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8081 DISCUSSION

The Royal Portbury Dock, Bristol

F. IRWIN-CHILDS, W. J. SIVEWRIGHT & P. T. SHAW

Messrs Irwin-Childs, Sivewright and Shaw

Among the interesting features in the scheme not fully dealt with in the Paper are the unusually large mitre gates with their unique action which has enabled the range to be extended. The latest comparable examples of locks built in Europe and Russia are all reinforced concrete cantilever structures of conventional form and proportions, built in open excavation in the dry, with a concrete volume ranging from 2 to 4 times that of Portbury. Indirect savings arose from the overall concept at Portbury and particularly from major excavation and filling executed in the dry.

71. There were constraints imposed by the largely rural site which nevertheless carried a number of public utilities which had to be maintained.

72. In the diaphragm work the closeness of the bond between soils and concrete was illustrated by the appearance of the walls after exposure. The greater thickness of the overlying silts was largely discounted when assessing the resistance to overturning of the structure, greater reliance being placed on the marl, the quality and dryness of which were shown after excavation of the cross-lock tunnels and the circular arch cofferdam.

73. There were no fatalities among the labour force over the 5 year construction period.

Mr A. J. S. Mansfield, Edmund Nuttall Ltd

The diaphragm walling contract at Bristol, on which I was agent, represented about 1% of all the world's diaphragm walling then constructed and was the largest single contract let for the Royal Portbury Dock.

75. My comments will be confined to construction details. The contract was undertaken by the joint venture of Edmund Nuttall Limited and SIF Entreprise Bachy of Paris. Possibly the greatest contribution to success made by Bachy was the grab which they brought to Bristol (Fig. 17). The characteristics which are noteworthy are the rope suspension, giving speed and simplicity of operation, and the long body which provided vertical directional accuracy so essential to the diaphragm walling operation. The grab dealt successfully with both the hard and soft ground found at Bristol.

76. There were 500 reinforcement cages in the contract which were necessarily constructed horizontally on the ground, and had to be lifted to a vertical position to place them within the trench. The danger of permanently distorting a cage during lifting was overcome by providing adequate bracing within the cage, by using a stiffening strong back frame externally and by utilizing two cranes to carry out the lift.

77. I should like to ask the Authors whether, with the benefit of the experience gained on other contracts since 1973, they would now adopt a different configuration for the panel layout, and in particular perhaps incorporate a shear connector such as the type used at Redcar.

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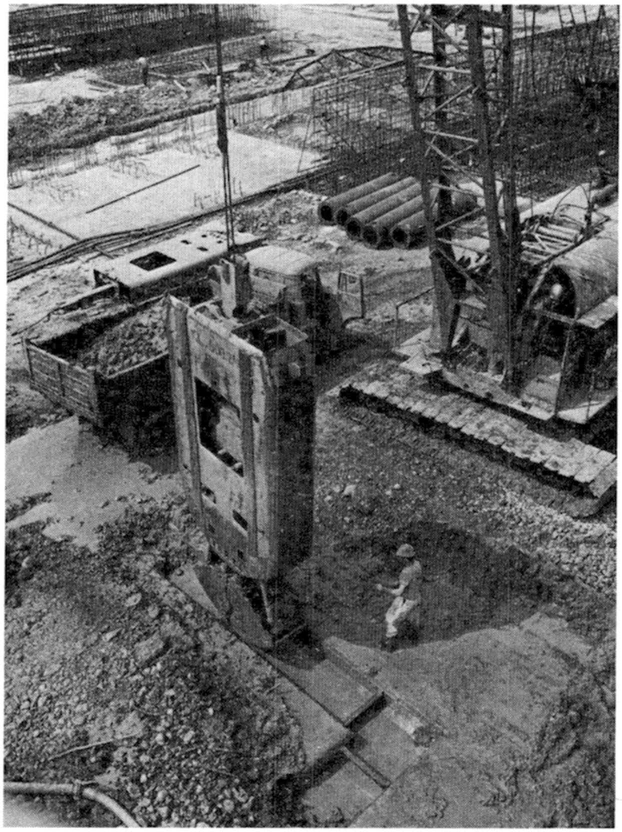

Fig. 17

Mr D. E. Glyn-Woods, John Mowlem & Co. Ltd

I was the agent on the construction of the entrance lock. Diaphragm walling was the key to the job, and as one of the contractors we also benefited from it, particularly in respect of the temporary bridge across the lock at deck level. This had to be 20 m above the lock floor level on a 43 m span, and sufficient to carry 60 ton dump trucks. The problem was solved by using two temporary piers in diaphragm walling.

79. There were six cofferdams for the construction of the by-pass culverts round the gates. Diaphragm walling was used on the outside where sheet piles would normally be used. The diaphragm wall panels were supported by concrete walings $1\frac{1}{2}$ m wide and 1 m deep, and they in turn were supported by steel tubular struts. These were taking up to 275 t, and so as to make them removable a concrete biscuit was introduced behind the strut with horizontal 50 mm holes at 100 mm centres through it. It was then possible to break the struts out by cutting from hole to hole.

80. The Authors mentioned the quoins for the main gates. These were of stainless steel castings 2 m high, 1 m wide and 100 mm thick, machined out to the correct radius, and weighed about a ton. A tolerance of $\pm 1{\cdot}6$ mm in 20 m is mentioned in the Paper but there was a tolerance of 0·2 mm in 3 m straight edge which was more onerous.

81. A datum was set up with two piano wires, using a micrometer. The plates were positioned with adjustable bolts, and preloaded with props to take up the deformation which would occur during concreting. After concreting, each plate was resurveyed and the adjustment needed to get within the 0·2 mm tolerance and within the overall tolerance of 1·6 mm and 20 m height for the next plate was worked out.

82. Instead of the usual granite sills a reinforced concrete sill was introduced. The tolerance asked for was 2 mm in a 3 m length.

83. A rigid shutter could not be made rigid enough, and a flexible shutter based on steel panels faced in ply was used. This was set up and supported by triangular frames bolted into the floor of the lock, with adjustable bolts at the top and bottom so that the face of the shutter could be wound backwards and forwards. A datum of piano wires was again set up; using a micrometer the face of the shutter was moved into position. While the concrete was still wet, the shutter was readjusted to bring it back into line.

Mr N. O. Taylor, Rendel Palmer and Tritton

Mitre gates form essentially a three-pinned arch in the horizontal plane, the total thrust into the vertical quoin of these particular gates being some 5500 t maximum. With the large mass and size of the gate it was necessary to ensure that at all times the machinery could adequately control the gate, the top and bottom bearings did not allow the gate to 'flog' as a result of wave action or change of thrust in the operating boom, and the mitres were held as firmly as possible in the closed position prior to the water head loading the structure. Since the gates at all times have to have a preponderance, to ensure that there is no tendency to lift off the pintle, the top anchorage is in a 'net' state of tension (there is some thrust upon the gate by the operating boom in overcoming the gate inertia and/or the resistance of the water which induces temporary compressive loads along the direction of anchorage ties).

85. The pintle or lower bearing takes all the vertical load of the gate plus the equal and opposite force to that induced in the top anchorage from the moment of the gate preponderance. One design criterion took into account the gate standing in a dry condition resulting in a pull or push of some 330 t.

86. While the pintle and top anchorage can thus be designed to take the resulting forces from a hanging and moving gate, they cannot be expected to take the very large thrust from the gates in their closed and fully loaded condition. Such a situation even at low differential level across a closed gate would result in leakage past the heel post, since it would not be possible to produce a sufficiently accurate, rigid and non-wearing structure that fulfils all the requirements. It is thus necessary to permit such a firmly held gate to move into the quoin under load to accommodate minor irregularities, running clearances and compressive strain, and, eventually, to take up heel post wear.

87. The bottom gudgeon into which the pintle seats consists of three nesting castings. The inner casting remains in constant contact with the pintle and is provided with a working tolerance to permit rotation about the pintle, and a small angle of rotation in a vertical plane. This inner casting can slide within the intermediate casting in a direction normal to the thrust of the gate preponderance; it is held against such movement by a rubber spring capable of permitting 25 mm of travel against an initial load of 15 t (Fig. 18).

88. The intermediate casting can itself slide within the outer casting and is similarly restrained from doing so by a larger rubber spring having an initial precompression of 75 t. This spring resists loads along the line of the gate, that is, in the direction of the resultant push from the preponderance.

89. Thus, in the closed position, the gate is held off the lock sill by a force of 15 t, and out of the quoin by a load of 75 t. Once mitred and loaded, the gate is able to move relative to the pintle in the directions that wear and compressibility of heelpost and lining would require. The amount of travel in the line of thrust is approximately 36 mm, while 25 mm is the maximum permitted loss of thickness of heelpost lining.

90. Wear should be eliminated by the centre of rotation being offset in relation to

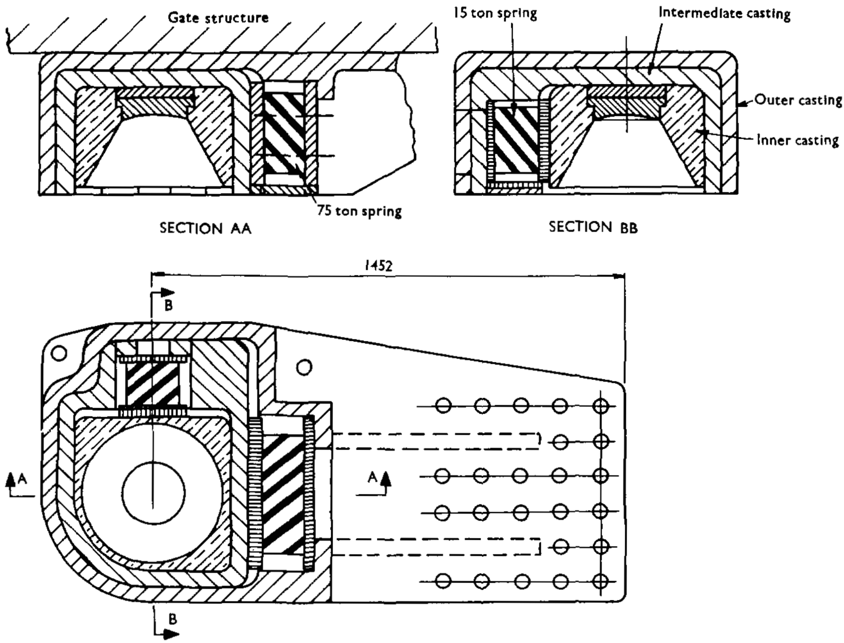

Fig. 18. Gate bottom gudgeon

the centre of curvature of the quoin (and heelpost in the closed position). The heelpost should just come into contact with the quoin when the gate closes.

91. At the top anchorage, the gate is held out of the quoin by the preponderance of the gate causing tension in the tie rods. The precompressed rubber springs of 25 t initial load are intended to reduce the 'flog' in the top anchorage and to ensure that the rocker under the bearing nut remains in contact with the thrust box mounted on the anchor beams (Fig. 19).

Mr M. Agar, Consultant

It is interesting to see that several features first used in the Seaforth Dock have been further developed at Portbury.

93. The cope level in the lock is +9·2 m, the same as that of the quays, 2·5 m above mean high water springs. I do not know the highest recorded tide at Portbury, but allowing 0·5 m above MHWS and another 0·5 m for wave height, this still leaves 1·5 m freeboard. If the cope level had been +8·2 m would there have been disadvantages outweighing the saving in cost?

94. The Authority preferred mitre gates. Does this imply that the Authors would have preferred a different type? The caisson gate is more positive and does not suffer the risk of mismitring.

95. An improvement developed by Mr Lyth of Liverpool has been the introduction of high pressure water jetting between the keel and the sill to avoid grinding, or the use of rollers with the risk of silt eventually getting into the bearings. This jetting lifts the caisson fractionally off the sill and wear is reduced to a negligible amount. This enables a larger preponderance to be used, thus adding to stability in storm conditions. Perhaps the Authors could give their views on the different types of gate, and their preference for the gates they used.

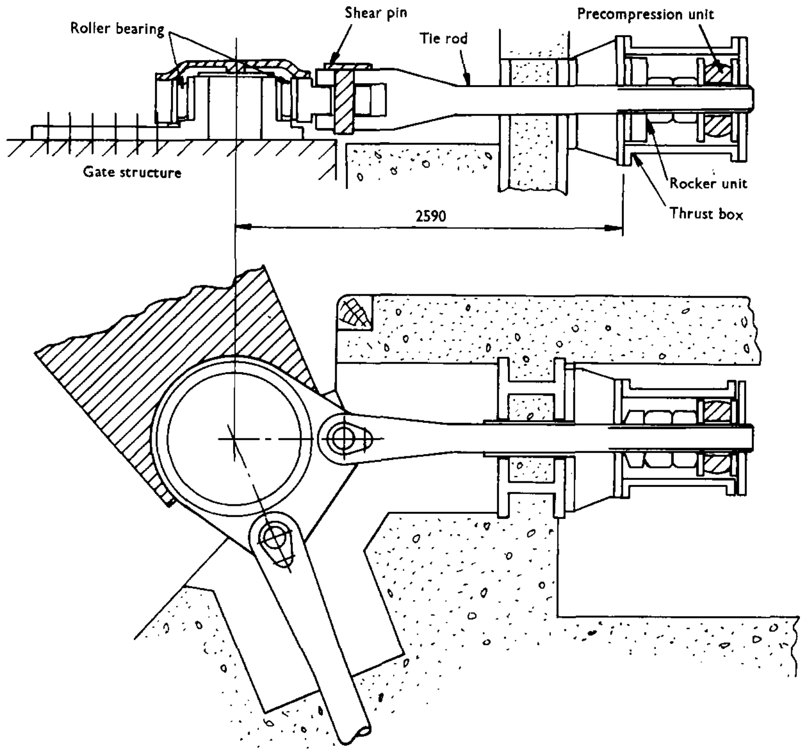

Fig. 19. Mitre gate top anchorage

96. A large number of independent contractors was used. Who was responsible to the Authority for their co-ordination, settlement of claims etc? I can understand the necessity for separate contracts for mechanical and electrical work and for site investigations, but what are the advantages of having several separate contractors?

Mr J. E. G. Palmer, Rendel Palmer and Tritton

The Paper mentions that there were two previous proposals for a new dock at Portbury and goes on to describe the second scheme. The original Portbury scheme, planned in the autumn of 1963 and the spring of 1964, was devised by the then Engineer-in-Chief of the Port of Bristol, Mr Terence Martin, one of the great port engineers of post-war Britain, who called in Rendel Palmer and Tritton to help.

98. In Martin's 1964 report he showed a Stage I development of nine deep water berths at an estimated cost of £27 million. My recollection is that the scheme did get through the National Ports Council, but was turned down by government.

99. In the Portbury 1 layout the proposed new entrance lock was also at the NW corner of the dock, but the bearing of the entrance from the point of view of incoming vessels was only a few degrees south of due east. The new lock as built has a bearing of about 130°, or very nearly SE. I was interested to see that initially twin piers were considered for the lead-in jetties. The downstream lead-in jetty has however been omitted on the recommendation of the Hydraulics Research Station, and the unusual length of the upstream lead-in jetty is also, as I understand it, their suggestion.

100. Will this long upstream jetty give protection to the heavily loaded deep draught vessels coming up towards Portbury with the flood on spring tides. A deep draught ship must make that entrance before the turn of the tide, and over the 4 h before high water springs the flood tide runs at 2–4½ knots. It seems probable that the pilots and ships' captains will be shouting for the protection of a downstream lead-in jetty as they try to turn across the tide towards the entrance, a swing of some 80° across the tidal stream.

101. I hope that the contract drawings, specifications and bills of quantities for that splayed off downstream lead-in jetty are ready, so that construction of the second jetty can be immediately put in hand as soon as the need for starboard protection on the flood tide is agreed.

Mr J. T. Williams, National Ports Council

Lord Rochdale said 'There is no doubt that some at least of the lack of investment in our older ports was attributable to their being hemmed in by a built-up hinterland and so to their having too little space available.' It was in this context that the Royal Portbury Dock, as it is now called, was conceived, and although, as a result of developing technology in cargo handling, the dock which is the subject of the Paper has a smaller number of berths than those provided for in the first phase of the original scheme, they are larger and provide for modern cargo handling operations. To quote Lord Rochdale again, they provide facilities which 'if not quantitatively, are at least qualitatively comparable to facilities provided in the major ports on the continent.'

103. The National Ports Council had many discussions with the Port of Bristol Authority and their engineering advisers over this development and the form which it should take. I like to think that the design owes something to the port structures report.[3] However, I would not wish to claim credit for the bold and imaginative use of the concrete diaphragm wall technique.

104. I find the design of the lock particularly interesting. I have long thought there was a need to reduce the cost where locks are unavoidable. A lock can be a very expensive 'front door'. Strong points are required at the gate positions but the walls between are required mainly to retain the water in the form of a barrel or tank. Bad ground can be a problem and monoliths have been used in such a situation, but these are expensive. I wonder if the Authors have any comment to make on the possible application of diaphragm walling techniques in extremely bad ground.

105. It is interesting to see the adoption of mitre gates of such large dimensions when in 1948 the ICE debated the question whether mitre gates were obsolete.[4] Only two pairs are provided and this could be a serious disadvantage if an accident occurred. The NPC has carried out a survey of the probability of accident damage to lock gates and the probability is relatively low.[5] The Port Authority at St Nazaire reported that over 30 years there had never been an accident causing damage to a lock gate with the exception of some misguided British Commandoes who damaged them with explosives, but apparently caused very little interruption to the port.

106. In some continental ports there is a trend where there is an extensive port system approached through a lock to provide double gates at the inner and outer positions. This reduces the probability of a catastrophic draw-down and presumably enables some economy in design of quay walls. The costs for Antwerp given in Appendix 1 seem to support this conclusion, although the quay walls were constructed in the dry. On the other hand, the insurance provision of double gates adds to the cost of a lock, particularly if it is a large one.

107. I should like to ask the Authors what provision has been made in the construction or design for the extension of the dock, and in which direction. The economies of the impounding system are referred to, and I wonder whether the Authors could say something about impounding pumps, the type and cost, and how this compared with a more conventional system, that is, without a pumping pond.

108. In the UK we have been well served by locks built in the earlier part of the

century which have only recently become outdated by the spectacular growth in size of ships. These locks were usually designed to accept the largest vessel afloat or planned at the time. European practice, however, has been to build very large locks, the dimensions of which are not necessarily geared to the size of a particular vessel. This enables several vessels to be locked in or out at the same time, which can have distinct operational advantages, particularly in a large dock system.

Mr D. Jones, British Transport Docks Board

Early use of diaphragm wall systems in the construction of the Hyde Park Corner Underpass suggested to me an exciting new form of construction which might have great potential for the construction of docks Since that time, I have watched with great interest their use at Seaforth Dock and the Redcar ore terminal berth. Here at Portbury Dock they are used in another way, but in a simple and elegant form.

110. During construction I was impressed not only by the economy of effort but by the enviable safety record. Works of this kind are not built without risk, but I believe that the elimination of cofferdams has significantly reduced them.

111. The Authors have said little about the commercial and marketing aspects of this new dock. Could they say something regarding the trade which is necessary to service this large capital investment.

112. In § 2 ships of 70 000 dwt are described as the largest which can navigate the approaches in the Severn. I assume the Authors mean the approaches to Bristol. Approaches to Uskmouth are not limited to ships of 70 000 dwt.

113. There were six berths in the first stage of development (§ 5). Does this reference apply only to the second proposed scheme, or is further development beyond six berths planned for the present scheme?

114. The Authors briefly describe (§ 45) the floating fenders in the lock. By how much is the effective width of the lock reduced and why are they required? The same paragraph refers to a concrete sill cast to a tolerance of ± 2 in 3000. Was any further dressing of the concrete sills necessary after casting?

115. I note that the lock will be operated with two pairs of mitre gates initially, but provision has been made for a third pair which will presumably be interchangeable with the other two. During the period when only two pairs of gates exist, the dock will be at some risk of interrupted use in the unlikely but not impossible event of ship and gate collision. What facilities exist for rapid gate repair within the port limits?

116. It is stated in § 36 that the floor of the lock does not act as a strut, but merely as a nominal scour protection with modest provision for pressure relief against uplift. Having had to face the consequences of upheaval to a lock floor, I should be very interested in hearing what investigations have been made to satisfy the Authors that the hard marl underlying the concrete floor is never likely to be subject to disruptive forces, especially in front of the outer gates. At the Newport Entrance Lock in the early 1970s there was disruption of the sill due to hydraulic uplift forces. The uplift destroyed some 60 ft of lock floor in front of the outer gates and lifted about 2 ft.

117. Will the Authors describe the steps taken to deal with siltation in the pumping pond? Trestle designs were considered for the upstream lead-in jetty but were abandoned in favour of continuous construction using steel piled sand-filled cells. This change would affect the rate of siltation in the bellmouth. Were any model studies done to assist in quantifying siltation rates and, if so, with what result? Would the Authors care to say what quantity of maintenance dredging it is estimated will arise out of the new works, and is there sufficient marginal capacity within the Port Authority dredging fleet to deal with it, or is a new dredger to be provided?

Mr P. G. Clutterbuck, Westminster Dredging Co.

I should like to speak about the dredging works which give access from this major civil engineering achievement to the Bristol Channel.

119. Two dredging contracts were part of this development: the dredging of soft

materials from the enclosed pumping pond undertaken by Seven Seas Dredging Ltd, using a small dismantleable cutter-section dredger, and the creation of the approach channel from the deep waters of the estuary to the entrance lock undertaken by the Ham–Westminster Bristol Consortium. It is the latter contract requiring hard dig—direct dredging—in exposed waters that I should like to cover.

120. A total of some 2·35 million m^3 was dredged to a level of -11 m, including hard Keuper marl and sandstone, to provide access in sea conditions that are among the most severe in England, with an extreme tidal range of 14·6 m. Currents in the early part of the contract were 4 knots, but as dredging progressed the estimated current on extreme spring tides rose to 6 knots and exposure over the open waters of the Bristol Channel from west to NE produced severe wave conditions, particularly when wind and current were opposed.

121. Apart from some 40 000 m^3 of foreshore mud removed to dump by a bucket dredger with barges, the works were executed by a large cutter-suction dredger cutting sea bed materials directly and pumping them to reclamation areas adjacent to the west dock. The dredger used was the *HAM 210*, at that time one of the largest and most advanced dredgers in Europe. It had a 140 h.p. cutter drive, and a total pump h.p. of 5800, of which 1600 were on the submerged pump, and a travelling spud carriage which allowed incremental movement of the cutter into the dredge face. There was also integrated automation which with the use of a radio tide gauge enabled automatic maintenance of a fixed level and cut width, and optimization of swing speed to maximize production. These features enabled much better control than is possible using manual methods alone.

122. The discharge pipeline was laid out as follows: a floating pipeline to an anchored barge with a 90° bend which minimized movement influences on the dredger, a further length of floating line to a connecting pontoon for a submerged pipeline laid on the sea bed up the foreshore and connected to land pipeline, giving a maximum discharge length of 2·7 km.

123. The dredged materials were discharged into bunded areas, the marl materials producing reclaimed land. It was only by adopting the cutter-suction technique that the Client could be provided with both dredged and reclaimed areas as requested. On this site there are examples of both dry fill from material excavated from the dock and fill over the soft alluvium by hydraulic techniques. I should be grateful if the Authors could comment on the quality of the fill produced by the two methods.

Mr D. J. Doughty, Doughty Associates

With regard to Appendix 1 the quay costs referred to have long been finalized and I am wondering whether the mention of half the cost for the West Dock quays takes account of all costs likely to be set against the job.

125. The Authors have been able to proceed with a large dock development without interruption or interference from traffic at other berths, in fact at a virgin site, which is almost unknown in the UK today. New quayage is generally additional to that existing and is only authorized when other capacity is taken up or the need arises for special new trades to be accommodated. For instance the container quay quoted in Appendix 1 was the first additional berth of a step-by-step development dictated by trade requirements and the change in the carriage of goods by sea. A true comparison between developments cannot therefore be drawn on the basis indicated as situations vary, and so do the forms of construction employed as a consequence.

126. At Southampton the quay wall mentioned was at the side of a turning circle provided for the large liners including the *Queens* and the construction had to be carried out through deep embankments. I would say a different situation existed at Portbury where the site was over virgin salt marsh lands. The Southampton wall height also was 17·23 m in the tidal range whereas at the West Dock the 16·8 m walls were constructed in the dry to form an enclosed dock. As described elsewhere[6] the geological formation at Southampton is particularly difficult and steel sheet and H piles were used to obtain

the wall depth required. Against the cost of the monolith walls put down in the 1930s and updated in the 1960s the construction cost worked out at about a third.

127. The Authors are to be congratulated on their successful construction of the West Dock employing diaphragm walling techniques. Could the Authors however say what difficulties were met and how the technique could be employed economically against the traditional forms of construction, particularly as far as docks being built in the tidal ranges are concerned?

Mr P. G. Hughes, Edmund Nuttall Ltd

In § 33 the Authors describe anchors as inappropriate: § 35 mentions that vertical anchors were installed where the marl was suspect.

129. In what sense did the marl differ from what was expected? How much reliance was placed, in the eventual design, upon cohesion between the marl and the rear surface of the diaphragm wall panels, as compared to the original design.

Mr A. D. M. Bellis, British Transport Docks Board, Humber

With regard to the quay loading, § 22 states a surcharge of $3{\cdot}5$ t/m^2 together with the loading from two adjacent container cranes was taken for the wall design.

131. This compares closely with 6 cwt/sq. ft at Seaforth, Liverpool and with the North Quay, King George Dock, Hull, constructed about 1960, but is low compared with the 10 cwt/sq. ft used in the design of Queen Elizabeth Dock, Hull, completed in 1969, and the apparent loading of 1·2 ton/sq. ft allowed for in the design of container quay S6 at Seaforth. Bearing in mind that Gordano Quay is to take container traffic, why is such an apparent low surcharge allowed for?

132. There is no obvious mention in the Paper of the design life of the dock and lock. In this day of calculated obsolescence in construction it would be interesting to know what useful life was projected for the facility, particularly in the light of its economic construction. Queen Elizabeth Dock, Hull (1969), an extension to an existing dock and therefore with no lock cost, has under half the area of Portbury but about the same length of usable quays.

133. With a water depth of 11·5 m its quay walls are constructed of Larssen No. 6 piles with thickened webs and cathodic protection, having a deck relieving slab and piled container crane rail beams etc. It was very economical in construction costs and it would be interesting to know if any similar construction was contemplated for Royal Portbury.

134. In § 51 the Authors indicate a locking sequence using water from the ponded area to save pumping energy costs. The procedure outlined would appear to substantially lengthen the normal locking routine, thereby causing possible delay to traffic, if not now perhaps later, once the dock reaches its full potential in terms of berth occupancy. Perhaps the Authors would care to comment on this and the extent to which they see this sequence being a regular practicable arrangement in the future.

135. Whilst this form of 'impounded' locking is intended also to save dredging in the dock it is inevitable that substantial quantities of silt will enter the dock, if only through the interchange of water during each locking operation. The presence of a dredger in the dock will therefore be necessary from time to time and the cost of extra dredging, had there been no ponded supply, might well have been cheaper than constructing the pond and the system of sluices.

Mr J. Simpson, Sir William Halcrow and Partners

If a reservation as to the suitability of diaphragm walling in the maritime environment were to be admitted, due to concern as to inclusions of soil, excrescences on the construction, and inability to ensure consistent provision of the required cover to the reinforcement, other solutions would have to be sought. This reservation would exist particularly if excavation of the dock basin were to be by dredging which had to be carried out up to the front face of the wall.

137. It would be most illuminating therefore if the Authors were to discuss any alternative types of quay wall which they had considered.

138. Did the Authors, perhaps in their 1967 solution, consider excavation in the dry, employing as a temporary measure the sheet piling used in the permanent solution and taking advantage of the opportunity to build a conventional in situ or precast reinforced concrete structure?

139. Although in the dock excavation dry excavation of the marl was considered an essential requirement for its subsequent use as fill, the use of dredged marl is also mentioned. I should be grateful for some indication of how suitable this material proved to be and of any special measures found necessary either to improve its quality, perhaps by mixing or interlayering with sand to accelerate its settlement.

Mr B. G. R. Holloway, Consultant

Mr Taylor has described the functions and advantages of the design of pintles adopted for the gates. These types of pintle were first used for the guard gate at Seaforth[7] but as this gate only fully functions in an emergency it is fortunate that their importance here has not yet been demonstrated. Similar pintles were originally proposed for the smaller mitre gates at Grangemouth but were considered too expensive and the traditional design involving slotted holes was adopted, to my mind a primitive mechanical concept.

141. At first glance the pintles would appear from Figs 18 and 19 to be over-elaborate but looking at the drawings again it is not immediately apparent how they could be simplified. However, this would be a matter for consideration in any future design.

142. Another aspect which contributed towards such large gates becoming a practical proposition was their analysis as 'stressed skin' structures, permitting the relatively small moulded width of 3·05 m. A computer program was developed for this purpose first for the gates at Leith then at Haldia (Calcutta) and the guard gate at Seaforth, with a saving of about 20% weight of steel over the more traditional method. The program for Portbury was complicated by the tapered ends.

143. To use this program, uniform skin and diaphragm plates are assumed. It then produces the varying plate thicknesses to meet the permitted stress requirements or limit state. The practical thicknesses are then determined (at Portbury the skin plate thicknesses vary in four steps: 22 mm, 18 mm, 16 mm and 12 mm) and inserted in the program to check that no unacceptable stresses are caused thereby. Thicknesses can also be increased to allow for corrosion in a similar manner, but with modern protective treatment this is not now felt to be necessary.

144. The protective system adopted at Portbury was pitch epoxy coating after blast-cleaning and priming.

145. A third feature of importance is the adoption of rubber seals, their size, shape and fastening. Rubber seals have been used in recent design of gates because, when the reactions on the sill and quoins were printed out from the above-mentioned program, it was found that they were negative at the lower corners, which explains why leakage has been experienced at these points using dressed timbers only.

146. Experience has shown that even the minor details under certain circumstances can prove important. Such details as access shafts and holes, manholes, ladders and sumps can make considerable difference to ease of fabrication and maintenance.

147. **Mr Agar** refers to the use of high pressure water jetting developed by Mr Lyth. Such a system using both high and low pressure has been considered for the various gates mentioned on a theoretical basis but it was not thought wise to adopt such systems without full scale experiments, which I understand Mr Lyth was able to carry out at Liverpool.

Messrs Irwin-Childs, Sivewright and Shaw

In reply to **Mr Mansfield**'s question whether we would adopt a different configuration and incorporate panel connectors in future design, we consider that the behaviour of the lock walls was satisfactory and that the stiffness factor of the structure did not require connectors such as were devised for Redcar where the depth was nearly double.

149. We were pleased to note **Mr Glyn-Woods'** approval of the use of in situ concrete in lieu of the more usual granite for construction of the sills, despite the fine tolerance specified. It was worthy of note that the sills required no dressing after casting. **Mr Taylor**'s detailed description and illustration of the provisions made for the gate hinges was appreciated and indicated how very large mitre gates could continue to be used.

150. **Mr Agar** asks about the advantages of having several separate contracts. This was an integral part of the economy drive and, with the onset of heavy inflation looming, was effective in enabling some contracts to be let earlier than they could otherwise have been, so saving considerably in cost.

151. By a special agreement between the Port Authority and the Consulting Engineers, the Authority's Engineer, West Dock, was the Engineer under all contracts. He was resident on site and with the assistance of the Consulting Engineers and their site staff issued invitations to tender, reported tenders to the Authority, procured authority for expenditure, placed contracts on behalf of the Authority, was responsible for the issue of all variation orders, issued certificates, chaired all co-ordination meetings with contractors, carried out negotiations with outside bodies, and was ultimately responsible for settlement of claims etc.

152. On the question of levels, the highest tide recorded at Avonmouth is $+8{\cdot}7$ m. The accepted level for sea defences in the neighbourhood is $+9{\cdot}2$ m. As the lock and dock quays in effect replace the previous sea wall, this level was adopted for their decks.

153. Visits made to various ports in the UK and abroad indicated that serious problems had been experienced at a number of locks with large caissons. Large mitre gates had operated successfully at Avonmouth since the turn of the century and the choice was made by the Authority largely on their experience.

154. Regarding **Mr Palmer**'s question as to the exposure of a vessel while making for the lock entrance, limited experience to date confirms the pier arrangement arrived at by model tests at the Hydraulics Research Station (§ 20), and the navigational manoeuvres demonstrated with a radio-controlled model ship. All the Authority's pilots observed the various manoeuvres demonstrated in the model.

155. On the flood the bulk of the tidal flow is diverted outwards along the face of the pier and thence along the training wall portion. The remainder sets up a clockwise eddy in the entrance with a velocity which was too small to be picked up in the model. The pilots find no difficulty in negotiating this situation, but the existence of the slow East–West current across the inner part of the entrance has, so far, demonstrated the wisdom of not providing a downstream pier.

156. **Mr Williams** asks whether there is any future for diaphragm walling structures in extremely bad ground. As he says, monoliths have been used in such cases but in a recent example in the UK they not only were expensive but had to be heavily strutted apart until completion of construction. The Authors believe that diaphragm wall construction could afford a real advantage in such circumstances though the design philosophy would be more unconventional.

157. On the choice of only two pairs of gates, also referred to by **Mr Jones**, the prime purpose of the third pair of gates is to save water when locking small vessels, but of course a third pair reduces the risk consequent upon damage to a gate. The budget did not permit the provision of the third pair at this stage.

158. There are no specific plans for a major extension of the dock beyond the six berths of the accepted layout, although room exists in the north-west corner for a small basin, possibly for roll on/roll off.

159. **Mr Williams** and also **Mr Bellis** enquire about the cost of the impounding system. Four pumps of the vertical shaft, trunk slung, axial flow type are provided for a maximum static head of $5{\cdot}5$ m. Maximum capacity is 11 650 m^3/h each. The cost was some £75 000 less than that of equivalent high-lift pumps operating from fully tidal levels,

while the saving estimated in the construction of the pond system was about £250 000 against the cost of equivalent low-level intake works.

160. In reply to **Mr Jones**, a survey of trade possibilities was commissioned before the project was embarked upon. Marked changes in world trade and economics and the onset of serious inflation have changed the picture during the construction of the dock. As a former President of the Institution and Chief Engineer of the Port of London Authority once said, 'No major dock has been constructed in this country except as an act of faith.' Floating fenders reduce the effective lock width by 2 m. They are necessary to avoid contact between the walls and medium-sized ships passing through the lock, at, say, half-tide, with their superstructures below cope level. Their design, as a train of units 11 m long, was based on the Authors' previous experience at Leith and Grangemouth.

161. The lock floor is liberally provided with pressure relief holes and terminates in a vertical cut-off some 2 m deep. Beyond the outer gate the resistance of the exposed marl to the effects of scour will have to be the subject of observation, as it has been at Avonmouth.

162. In reply to **Mr Doughty**, the quay costs given for Portbury were understood to be final. Obviously the long list of works given in the NPC report[3] covers a range of conditions but the contrast in costs is still significant. Diaphragm walling can be used in tidal conditions as long as a working platform can be provided at an appropriate level.

163. **Mr Hughes** mentions the anchors, described in § 33 as being inappropriate. This reference was to horizontal ground anchors deemed inappropriate where the embankments were newly tipped or intended to be removed. The structures had therefore to be self-stable and vertical anchors were used where the marl, anticipated from trial shaft inspection to be Zone II–III on Chandler's scale,[8] was found on larger exposure to be Zone III–IV. The reliance placed on cohesion between the soil and the concrete was considerable and fundamental but by no means confined to the rear of the walls.

164. Replying to **Mr Bellis**, it is considered that the surcharge assumed is adequate for container handling since it is in addition to crane loadings, and stacking would normally be behind the 11 m wide apron. As to longevity, there is no reason for this to be considered as diminished by reason of the economy of the type of construction. (On the contrary the strength of the concrete, cured as it is under ideal conditions, is as good as if not better than most in situ construction.)

165. As to the question of efficacy of the impounding system there can be no question that using tidal energy to raise the water to high tide level must be advantageous, especially when the head lift and length of main are each about one third of what they would be with an offshore pumphouse, apart from the saving in capital cost. If the required locking time is too short to use gravity flow from the pond it can all be done through the dock sluices and made up by pumping at leisure from pond to dock.

166. The anticipated amount of siltation was assessed qualitatively by comparing the regime and extent of the entrance at Portbury with those at Avonmouth. Limited experience to date indicates that the Authority's suction dredger will cope on two shifts.

167. Scouring the pumping pond through the side-levelling culverts has been tried with encouraging results. A small suction dredger could pump over the embankment or along the pier into fast flowing water.

168. In reply to **Mr Simpson** as to whether any other designs were contemplated, the previous proposal (which was by others) was intended to be the most economical scheme obtainable by conventional practice. The whole point of this Paper is that such proposals were no less than 50% in cost above the acceptable target, and the comparative costs collected in the NPC report also confirm that none of the many varied structures of comparable depths could match it either.

169. On the question of the use of steel sheet piling, also raised by **Mr Bellis**, the required level for dock bottom was 2–9 m below the marl horizon, which precluded the economical driving of face piling to a lower level. The cut-off piling initially driven

around the dock was unstable without the supporting structure and would in any case have been quite inappropriate in relation to the lock.

170. As to reliability of the method, experience had shown that concern over the shortcomings feared by Mr Simpson was not needed. In this application the structures were exposed by subsequent excavation but the deep cellular berth at Redcar was in fact excavated by dredging and inspected by diver.

171. The Authors are grateful to **Mr Clutterbuck** for describing matters for which there was no room in the Paper. Marl dug in the dry was placed in areas immediately behind the quays. The only consolidation was provided by the earth-moving equipment. Dredged marl was pumped further afield to areas likely to be developed later and so was given longer to consolidate. Experience to date suggests no apparent difference in the results of the two methods of placing.

Errata

§ 39, line 6: for 'lock panel' read 'lock barrel'.
§ 55, lines 3 and 10: for 'West' read 'Royal Portbury'.
§ 58, line 4: for 'low and high tide' read 'high and low tide'.
Appendix 1: the items should be numbered from 1 to 14, to relate to Fig. 14.
Appendix 1, line 18: for 'West' read 'Royal Portbury'.

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7. HOLLOWAY B. G. R. *et al.* Passage gates for Seaforth Dock, Liverpool. *Proc. Instn Civ. Engrs*, Part 1, 1973, **54**, May, 239–254.
8. CHANDLER R. J. The effect of weathering on the shear strength properties of Keuper Marl. *Géotechnique*, 1969, **19**, No. 3, 321–334.