

Oil jetties at the Port of Hull

by

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and

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The Chairman, Mr W. G. Harris, said that he was very interested in the lengthening of the piles. It seemed from § 34 of the Paper, that the question of having to lengthen the piles came as something of a surprise. He wondered whether any test piles had been driven earlier or whether these difficulties were anticipated in any way. To have to lengthen so many piles during the course of driving must have slowed down the job quite considerably.

56. He was interested in the statement in § 17 of the Paper that 'the design of the jetty heads was largely influenced by the choice of the most suitable fendering scheme, which for Salt End was found to be a system of steel fender posts cushioned by solid cylindrical rubber blocks'. No explanation was given why this was the most suitable type of fendering and why the fendering governed the design of the jetty. It would be interesting if the Authors would comment on it.

Mr P. K. Brown (Chief Docks Engineer, Hull) said that he wished to echo the sentiments and tributes paid to the late Mr Lloyd by the Authors. Mr Lloyd, as Chief Docks Engineer and as his own chief, had been intimately involved and intensely interested in all the developments at Hull and it was with his support and encouragement that the Authors had been prompted to present their Paper. Had he been living, he would certainly have been present.

58. He congratulated the Authors on their presentation of the Paper and their introduction to it. It was clear, concise, and excellently produced. He wished also to congratulate Messrs Coode and Partners, the Consultants, and Yorkshire Hennebique Contracting Co. Ltd on combining to produce a very clean and workmanlike structure which went to improve to a great degree the facilities at Hull docks.

59. He could most usefully contribute to the Paper by giving a brief description of the dredging associated with the provision of the berths, to complete the record of the works. The dredging required was mainly concentrated off No. 3 jetty and its approaches to give the required depths of water there. The new No. 1 jetty being sited forward of the old timber jetty was built where deeper water already existed.

60. The material to be removed consisted of silt, boulder clay, and laminated clay. The dredging was undertaken by the British Transport Docks Board using their Humber-based bucket dredges *David Dale* and *Oliver Bury*. These were served by three steam hoppers, *Princess Channel*, *Joseph Phillip*, and either No. 14 or No. 15 as available, each of the hoppers being of about 600 tons capacity. Approximately 90% of the dredging was undertaken by the *David Dale*, but the purpose of the *Oliver Bury* was to clean up alongside the jetty faces because of her longer outreach. Of the craft used, only the *Oliver Bury* now remained in service,

the other craft having been scrapped or sold to make way for new grab and suction dredges which the Board had provided under their policy of modernization of their Humber dredging fleet.

61. Because the dredging depth of the *David Dale* was limited to a maximum of 45 ft below water level, dredging was limited to the period from about 3 hours before to 3 hours after low water.

62. The amount of material actually raised was 425 420 hopper tons, and the spoil was deposited on the Foulholme deposit ground some 7 miles downstream from the jetties. The total cost of this dredging operation was £69 150, equivalent to 3s. 3d. per hopper ton. The laminated clay was prone to erosion by the tide and it was found during operations that appreciable quantities were carried away by this means. The dredging was undertaken in four stages and the whole work was completed in 28 working weeks.

63. The Authors had pointed out in § 3 of the Paper that the jetty heads were sited riverward of the timber jetties and on the edge of the main channel to minimize dredging. In fact, the main berths at the jetties were to a certain degree self-maintaining as predicted, but it was found that fairly regular attention was necessary to clean up and maintain depths off these berths.

64. It was also hoped that the barge berths at the rear of No. 3 jetty, which were well outside the limits of the line of mean low water shown in Fig. 1, would be largely self-maintaining. Since the jetties were built, however, the line of M.L.W.S. had advanced and the scour which was expected to keep these berths clear had not been maintained. Some maintenance dredging at the barge berths was therefore probable, although none had been carried out to date.

65. To supplement the information given by the Authors, the largest vessel so far berthing at the jetty had a length of 666 ft 4 in., a beam of 81 ft 2 in., and a dead-weight of 28 400 tons, but unfortunately she carried only a part cargo.

Mr A. E. Murray (Contracts Manager, Yorkshire Hennebique Contracting Co. Ltd) recalled that he was concerned with the direction of the job during the whole of the construction period except for the first seven or eight months and during the whole of that period he was closely concerned with the Authors in the execution of this somewhat complicated contract. He wished to take this opportunity of paying tribute to the Authors for the manner in which they carried out their respective duties and, at the same time, to compliment them on their presentation of the Paper. Unfortunately, in the space allowed to them, they had had to omit much that might be of interest to members. Hence, he could well contribute further details on certain aspects of the construction.

67. In particular, he wished to make reference to the piling difficulties encountered towards the river end of the No. 3 jetty approach, which had been referred to in the Paper. The approaches to the jetty heads were constructed on precast piles, but Rendhex piles had been adopted where longer piles were necessary at the end of the approach and in the jetty heads themselves. The first indication of possible difficulty with the piles came shortly after the changeover, in as much as they started going down.

68. Most of the piles in the portion from the changeover to the No. 3 jetty head and also on both of the dolphins, referred to as E and F, were found to require extension. This was rather alarming, and on plotting results achieved up to that time there appeared to be the distinct possibility of some sort of fault in the substrata at this point, and there was every indication that the piles in the head might well require extensions.

69. In fact, all but very few of the 225 piles in No. 3 jetty head had to be extended, and of these at least 50 had to have a second extension piece added. Towards the downstream end of the head itself, the hard solid chalk to which they were being driven could not be reached until, in some cases, about 140 ft of pile had been driven.

As could be well imagined, these wholly unforeseen difficulties caused delay to the contract.

70. Due to the fact that a very large proportion of the piles were driven to varying slopes up to a maximum of 1:3, it was necessary in the case of the raking piles to place the extension piece on to the pile frame so that the welder could make the splice. The whole operation of preparing the pile, adding the extension piece, and welding took upwards of 5 hours to complete. The frame was therefore engaged for this period, and so that progress could be maintained, it became obvious that a second pile frame—the one referred to in the Paper—must be provided to permit continuity of pile driving.

71. No less than 483 welded splices were made on piles, almost every pile having a weld on it. These were all made by one highly-skilled welder, whose workmanship was put to very thorough test before he was allowed to weld any single splice. It was, therefore, a tribute to his skill that both jetty heads were carried on the piles which he welded.

72. As a result of the extraordinarily long piles which became necessary, the layout of the building in No. 3 head and under strong point F, i.e. the point immediately adjacent to the junction where the approach met the head, became very complex indeed. Since the piles at that point were raking at different slopes in several directions and meeting piles coming from opposite directions and in all manner of slopes, it was necessary, as in the case of the root manifold, to fabricate a small model introducing $\frac{1}{4}$ -in. rods in the planned direction in which the piles were to go to permit accurate determination of the correct setting of the pile in the frame for driving. This was necessary because the piles were at that point 40–50 ft longer than designed; what was indicated in the drawings would have been satisfactory but for the extensions.

73. When driving a pile 120 ft in length at a slope of 1:3, the toeline was some 40 ft away from where it entered the water; if another pile was 80 ft away, there was a distinct possibility of the two piles striking one another. There were one or two instances where one pile suddenly struck another opposing pile, but it glanced off and driving could be continued. Nevertheless, a serious problem was posed and great care had to be taken in the actual pitching of each individual pile.

74. The Authors had not been able to say very much in the Paper about the actual shuttering which was necessary to carry out the construction of the deck slab. This was very complex and considerable ingenuity was needed to overcome some of the difficulties encountered. These were created largely by the fact that 50% of the piles in the jetty head were raking, not all parallel to one another. They twisted in various directions so that they would not foul one another. This meant that it was difficult to get adequate support on the piles. The baulk timbers referred to in the Paper had to be carried on brackets, but they could not be securely clamped to the piles as would be done in the ordinary case with vertical piles.

75. The piles were in pairs. One of the Authors' slides had shown two piles in the second row with a pile cap on top, but not attached by beams to any of the inner or outer beams, which meant that the 18–21-in. thick deck slab had to be supported over a span of 40 ft. That was why it was necessary to introduce the steel joists. It had, in fact, been possible to overcome all the problems, but not without considerable effort.

76. Construction of one of the dolphins was close to tankers discharging at the existing No. 1 jetty head. On such occasions, when the tanker was blowing out its tanks after discharging, all work in the area had to stop. In the case of a big tanker, the stoppage was often for a considerable time.

Mr A. F. Lambert (Associate, Messrs Coode & Partners) said that the Paper gave the combined viewpoints of the Resident Engineer and the Contractors and he wished to make a few remarks from the third point of view, that of the design office. The design of the jetties had undergone a number of transformations before being finalized.

For instance, No. 3 head was originally bifurcated. It was shaped rather like a tuning fork, with two parallel arms and a strip of water between, the rear arm being designed as the barge berth with provision for berthing on both sides of it, while the front arm was for the large ocean-going ships.

78. The design was later superseded by the ordinary rectangular design, which in its original form consisted of two strong points, one at each end, with a central portion set back about 6 ft behind the cope line of the strong points so that the whole of the berthing blows and bollard pulls from the large ships was taken by the strong points and the central portion took the vertical loads of the pipe headers and the hose-handling gear, together with the barge berth fendering and bollards. This design had many attractive features and it held the field for quite a time. It was eventually abandoned, rather reluctantly, because the 6-ft gap between the face of the central portion and the side of the ship was regarded as a hazard for operatives and any attempt to deck it over would have spoiled the whole idea of the design, which was that the central portion should not take berthing blows. The only alternative, which would have been some sort of protective railing, was also objectionable from the operational standpoint.

79. The fendering had been referred to several times already. One of the main factors which affected the design in its final form was a desire to avoid the necessity for heavy reinforced concrete work near low water springs. In the very early days of design, before the extreme range of freeboard of the ships using the jetty was known, the fendering consisted of 15-in. diameter tubular rubber fenders closely spaced and laid diagonally against the backing of a heavy reinforced concrete curtain wall. This would have been satisfactory as long as there was no need to cope with very small freeboards, but when freeboards of no more than about 18 in. were introduced it was obviously out of the question to do heavy reinforced concrete work within 1 ft or 2 ft of low water springs, unless the contract period was to be extended astronomically. In fact, the combination of a considerable tidal range with very wide variation in the freeboard of ships using the jetty was a headache. It would be of interest to know how the design finally adopted had withstood two or three years of ordinary wear and tear.

80. Reference had also been made to delays due to the lengthening of the piles. One point which affected the situation was the difficulty of subsoil investigations at the site in question, as a result of which they were not nearly as extensive as people would have liked.

81. The layout plan in Fig. 1 of the Paper showed that the position at No. 1 head was right, for the new head was quite close to the existing head, which could be used as a base of operations. No. 3 head, however, was not nearly as well situated. There was no existing structure anywhere near it. It was in an exposed position where, apart from the natural difficulties of the site, it would be necessary to cope with the rather stringent regulations for the protection of shipping.

82. The same objections also applied to test piles. A provisional sum was, in fact, included for test piles to No. 3 head in the early stages, but they were not driven for the same reason.

Mr J. A. Williams (Messrs Sandford Fawcett, Wilton, and Bell) said that the two aspects of the Paper to which he wished to refer were the construction of the approach jetty and costs. The approach jetty referred to in §§ 29–32 was a very long structure over mud flats which were quite unsuitable for the use of floating plant. Furthermore, because of the length of approach, there was a great repetition of construction and there were many permanent piles. It seemed obvious that the design of the approach jetty should have been based on the most economical construction method.

84. Following that line of thought, it further appeared that the most economical construction method would be end over end, using the permanent piles and the permanent structure as the Contractor's working gantry, cantilevering ahead with some

form of outrigger frame for the next bent ahead exactly as was done in jetty head No. 1 apparently. By this means, it was possible to avoid all the temporary works and all the floating plant. It seemed to have been ruled out, however, by the significant statement in § 29 of the Paper that the high degree of precision called for in driving the permanent piles led to the use of temporary staging.

85. He wished to ask the Contractor, whether, if he had been allowed a tolerance of, say, 6 in. in any direction for the permanent piles in the approach jetty, his construction method would have been somewhat different and would have enabled him to submit a lower tender.

86. If the answer was affirmative, as he was sure it must be, he would like to ask the Engineer why the specification called for such a high degree of precision in the permanent piles of the approach jetty. His own view was that there would have been no difficulty in designing a transom beam which would have allowed for 6-in. tolerance and still enabled the precise erection of columns and superstructure in their correct position and true alignment. This would have preserved the appearance of the superstructure; the slight non-alignment of the piles themselves would have been of no consequence as this particular 'view' would never be seen.

87. Could the cost of the fendering be given for, say, one lineal foot of jetty face and also the cost per square foot of the jetty heads? Were the prices quoted the actual cost of the works as built, including all the pile lengthening?

88. Following from that, he could not reconcile the figures for No. 3 jetty head and No. 1 jetty head. For example, did the £160 000 for No. 1 jetty head include the pipe gantries and work above deck level? Could the Authors give a figure for cost per square foot of No. 3 jetty head and No. 1 jetty head at deck level, ignoring the material above? What was the explanation of the apparent marked difference between the two figures?

Mr R. A. Fisher (Assistant Engineer, New Works, British Transport Docks Board) said that numerous papers and reports had been presented in recent years describing the construction of oil tanker berths, and analysing and summarizing the forces imposed upon them by large crude oil tankers of about 30 000 dwt and upwards. The present Paper was worthy of attention in that the structure described served several clients with different requirements and accommodated a variety of vessels, both singly and in combination up to a maximum of 27 500 dwt each.

90. Having had some association with the project in the very early stages of design, he was in a position to appreciate the widespread complications that this variety of activity imposed upon both the Consulting Engineers and the Contractors. He congratulated both parties on the completion of a project which, in the circumstances of having to please everybody, was straightforward and economical and reasonably efficient.

91. Prompted by Mr Williams' reference to the approach jetty, he had a weakness for the long straight line in works of civil engineering construction and he gave credit to the Contractors for the well-nigh flawless appearance of the 1200-ft long approach jetty with its raking piles and two-tier precast gantry frames, which challenged anyone to cast an eye along them in an effort to find a post or beam out of line.

92. More specifically, he wished to refer to the arrangements and detailing of the fendering system. In this respect, he was interested to hear Mr Lambert's reference to early designs where the central part of the jetty heads was set back behind the strong points located at either end.

93. There were slight differences between the two berthing heads, No. 1, the shorter, having fender posts at each bent and No. 3 having two posts transmitting their thrusts to one bent. In this case, of course, there must of necessity be a lower waling of considerable strength which would have advantages other than merely supporting the intermediate fender posts.

94. Both the No. 1 and No. 3 heads had splayed ends, as described in the Paper,

and this was a logical arrangement and a common feature in tanker berth layout. However, the continuation of the same kind of fendering across the face of the heads between the splayed ends was not as logical. This could be seen from the plan of No. 1 head in Fig. 4 and the photograph of the No. 3 head in Fig. 6. The splayed ends consisted, in fact, of two divergencies, each extending over 21 or 27 ft depending on the jetty head, and possessing three posts, including the corner ones.

95. His continued reference to the fender posts was to ensure that there would not be any misunderstanding that he was not referring to fender units, the individual buffers. Each post had two buffers. The first splay from the face of the jetty head appeared to be something over 2° and the outer splay about $6\frac{1}{2}^\circ$.

96. It would appear that one of the reasons for assuming that two fender posts absorbed the transmitted energy from a berthing ship could be an impact occurring on a corner post between the diverging faces, which when fully deflected would allow the two adjacent posts to be about half deflected.

97. The point was that a ship berthing at an angle of less than, say, 1° would impinge upon a number of posts in the front face, the number increasing as the angle of approach decreased.

98. It was a pity that the Authors had not been able to go into more detail regarding the berthing of coastal vessels at No. 3 head. Admittedly, small vessels could cause as much damage as larger ones if their approach was not fully controlled; but, even so, one would have thought that a closer grouping of fender posts around the centre of No. 3 head than that visible in Fig. 6 and omitting some of the others, would have been preferable.

99. One of the alternative schemes proposed in the early days showed a concentration of flexible fendering at each end of both heads, with, in the case of No. 3, two intermediate groups located around the third points of its length. Under such an arrangement, the heavy lower connecting waling which had been adopted in the actual construction might have been used to resist accidental impact from small ships between the groups and the total number of fender posts reduced accordingly. This appeared to apply even more strongly on No. 1 head where the fendering was uniform across the face, although it did not seem that small vessels would normally berth there.

100. Apart from questions of economics, there was surely an engineering question arising from the use of more fenders than were really needed. Most investigations into berthing forces were based on considerations of angular impacts resulting, as in the case of the present Paper, in the selection of a small number of fenders to absorb the energy; but near-parallel berthing was not unknown and, in fact, under ideal conditions would be the rule rather than the exception.

101. In such circumstances, any increase in the number of fenders brought into contact with the ship would have the effect of increasing the overall stiffness of the fendering system, resulting in a quicker halt to the ship's movement and an increase in the force transmitted to the jetty.

102. That had been demonstrated on a recent visit to Salt End where, during the berthing of a tanker of about 26 000 tons displacement at No. 1 head, conditions were good and the velocity of approach was visually estimated at 6 in./s. The vessel's divergence from parallel at impact was only about 1 in 150. The after part of the tanker struck the first fender post of the parallel face of the head. The remaining fenders rapidly came into play until, when the forward part struck the last fender, there was no discernible compression. Presumably, all the energy had been absorbed by, perhaps, 18 fender posts in a matter of a second or two, and the vessel then swung away from the face. Admittedly, this observation was entirely visual, but for what they were worth the following figures illustrated the point.

103. Had the initial impact been taken by two fender posts only, the total force transmitted to the jetty as measured by the calculated pressure on the rubber buffers would have been about 240 tons, whereas the total force from the near-parallel impact

might have been in the region of 540 tons. All this, of course, had no effect on individual fenders and jetty bents which were designed for maximum concentrated loads, but the effect on the ship of the quicker deceleration was both undesirable and, in this event, unnecessary.

104. In the design stage, after a preliminary fendering unit had been arrived at, there would appear to be an opportunity for an adventurous mathematician to evaluate the optimum overall stiffness of the fendering system if it was to be extended to protect a jetty face, in relation to the stiffness of the jetty structure, because the greater the quantity of fendering, the less effective it became when near-parallel berthing occurred.

Mr G. W. Roberts (Holmpress Piles Ltd) said that he was connected with the project in the early days and thought that the tender was won by the decision of the Contractors to carry out an independent staging all the way from the shore. At the time of tendering, it was obvious that others had ideas of supporting and driving from a platform on the permanent piles and also by heavy floating plant. This information was obtained from people who asked why they could not quote a price for plant suitable for these methods. One could, of course, price the cost of a temporary staging out in the water, but one could not price the time that would be lost when trouble was encountered working end over end and the resultant delay to the work, and, more particularly, with floating plant. It had always been said that the cost of working from floating plant was at least double that of working from firm staging, and it could be multiplied many times over when there were rough seas.

106. The only fault of which he was aware in the jetty—and it was referred to in the Paper—was the initial cracking in the precast piles at the shore end. Having given a lot of thought to piles in similar circumstances throughout the years, he had come more and more to the conclusion that the design of the toe of the piles was at fault.

107. The first time he had encountered this difficulty was when driving 10-ton precast piles in a bank. When a 5-ton hammer was used on them, the piles cracked. They entered the ground, but there was less resistance on one side than on the other. When held in guides above the ground, the piles cracked. The difficulty was overcome by having a level seating of some depth in the bank into which the pile was pitched (Fig. 13).

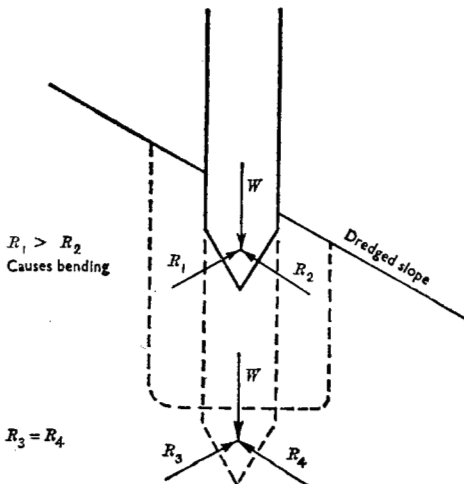


FIG. 13: VERTICAL PILE

108. There was a similar position in the present instance. The pile was driven on a rake. When the pile was driven vertically, there were forces normal to the sides of the toe. As soon as a raking pile was used (Fig. 14), the reaction at one side must be higher than at the other. As soon as this occurred, there would be a bending force in the pile which cracked it.

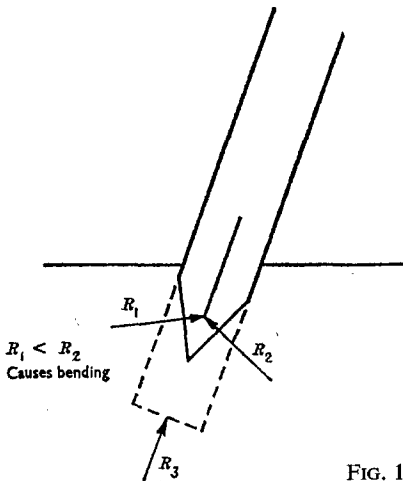


FIG. 14: RAKING PILE

109. There were two possible answers. One was to have special shoes made which were calculated out to the right angle, but this could be difficult. Probably the real answer was to have a flat bottom to the pile.

110. It would be interesting to know whether the Rendhex piles driven with a flat end or an open end showed any inclination to divert when driven on a rake. Experiments in driving steel tubes with flat or pointed shoes had indicated that there was no difference in the sets obtained when driving through alluvial ground, and they certainly drove straighter with a flat than with a conical shoe. A lot of rethinking was necessary on the shape of pile shoes. This might even give the answer to raking precast piles. Experiments in this direction could profitably be carried out.

111. The other reference to the Rendhex piles was the experiment with fins, in which the Authors had said that there was no difference in the driving resistance. His own view was that driving resistance in the ground in question did not mean a very great deal. This was obvious from the fact that when a pile was driven and left for a few days, it was much harder to start moving when it came to be driven again. The ultimate bearing of the pile would have nothing to do with the driving resistance that was encountered.

112. He felt that if the piles with the extra fins had actually been tested, the extra area of the fins might have increased the bearing capacity of the piles. He did not mean that the ground was good enough to take the desired load without going down to the depth, but he thought that it would have increased the capacity.

113. He congratulated the Authors not only on their able presentation of the Paper, but on the successful construction of a difficult project at the mercy of the elements.

Mr A. S. West (Holmpress Piles, Ltd) agreed that the finished structure was pleasant, tidy, and clean-looking. Having been in both the contracting world and also in the oil industry, he knew how difficult it was in dealing with pipelines to get something that looked even reasonably tidy.

115. The main point of his observations was to ask the Authors questions concerning the results of the pile tests shown in Figs 9, 10, and 11. He was interested to see that in the first two loadings in the second stage, after applying a 20-ton load when the pile went down 0.075 in., it actually rose 0.008 in. in the succeeding period of one hour. The load was then increased to 40 tons with a further deflexion to 0.173 in. and again, in the succeeding period of one hour, the pile rose a matter of 0.007 in. Did the Authors know the cause of this?

116. He had met a similar result under slightly different circumstances on the Barking Marshes, where there was actually a change in level, presumably, between the different strata. As the tide rose, so the pile tended to come up, i.e. when checking one pile against another of a different length.

117. Similarly, as reported in a paper given at the Institution 30 years ago, tests had been made on the foreshore at Dagenham during the construction of the Ford jetty. In that instance the reverse process was discovered in that, as the tide rose, the foreshore went down. This followed, of course, from the extra weight of water bearing on the peat.

118. The other curious effect which he wished to raise with the Authors was in stage 3 of the pile test. After 20 tons was applied, the pile continued to move downwards during the succeeding hour, but after 40 tons was applied it remained stationary for the next hour. With 60 tons, it continued to move downwards for the following hour, but with 80 tons it remained stationary. After 100 tons was applied, it went down considerably by 0.03 in., but at 120 tons it stayed quite stationary for the hour after the load was put on. Had the Authors any idea of what happened?

119. He wondered whether the Authors could explain the strata in the neighbourhood of the test pile. The results of a test such as they had given were extremely valuable, but it would be even more valuable to know the strata at that point. Admittedly, they had difficulty in getting strata details, but, having got something off which to work, they might have taken a check test boring.

120. According to § 39 of the Paper, with the exception of the test pile and about a dozen others, all piles were driven with open ends. This might have been because of the point raised by Mr Roberts when speaking of the difficulties of driving raking piles and keeping them straight or on line. It seemed interesting, however, to have driven and tested a pile with a shoe and then driven all the other piles open-ended, although eventually, when the piles were filled with concrete, their load-carrying capacity would presumably be the same as before.

Mr D. G. McGarey (Chief Engineer, British Transport Docks Board) said it occurred to him that some of the audience might be rather puzzled by the mixed references, both in the Paper and by some of the speakers in the discussion, to the British Transport Commission and the British Transport Docks Board. The two bodies had never existed simultaneously. It should, perhaps, be made clear that throughout the whole period during which the jetty was designed and under construction the British Transport Commission was in the saddle; the British Transport Docks Board had only inherited the final demolitions referred to as having taken place in the early part of 1963, as well as, possibly, the settlement of contractors' claims. This, however, was a matter about which he could not speak.

122. The references in the Paper to dates were rather scanty; the only mention being the completion of the respective heads, No. 3 head in August 1961 and No. 1 head in November 1962. He would like to have seen a reference to the date on which the work was started and the times occupied by the various stages of construction. His own diary seemed to show that the reclamation, which was carried out departmentally for the benefit and convenience of the Contractor, was finished in March 1958. The Contractor was thought to have entered the site shortly afterwards but it would be helpful to be given more information about this.

123. It had been obvious from the Paper that the jetty was rather unusual in

having to deal with the multiplicity of pipelines required for the variety of refined products, unlike jetties designed for handling crude oil in bulk. Another point of interest was the relatively small size of tanker which the jetty heads were designed to accommodate. There was no question of having to deal with mammoth tankers, which were hardly thought of when the design was prepared, and which in any case were unlikely ever to be able to come up-river to Hull. What was impressive on studying some of the figures given in the Paper was the good use to which the jetty appeared to have been put. To handle $2\frac{1}{2}$ million tons in a year from a succession of small vessels—very few vessels reached the 27 500 dwt limit, and from the figures the average seemed to be less than half that figure—was very good use.

124. He hoped that the Authors would forgive him for pointing out that one or two of the levels required a certain amount of adjustment. The design depth of 36 ft below M.L.W.S. was at the old value taken for spring tides up to 1958. The present value for high water springs was 12.12 ft O.D., about 1 ft higher than shown in Fig. 5, and for low water springs—9.88 ft O.D., about 10 in. lower than the corresponding value shown in the same figure. Thus, at current values, there was about 35 ft 2 in. available at M.L.W.S. On average, the 27 500-ton tanker drew about 33 ft fully laden, which would still leave 2 ft of flotation at M.L.W.S.

125. Could the Authors give a little more information about the protective coating given to the piles? The Paper stated that coats of coal tar enamel were used but to his own knowledge a great amount of thought and research had been devoted to the type of enamel or protective coating which should be used on the piles. It would be helpful to others faced with a similar problem of protection against marine corrosion to know a little more specifically what was tried and found best.

126. The steel fender post assemblies, which had excited comment, appeared to invite trouble in one or two directions. The posts, with their travel guides and friction plates, seemed to be designed on the assumption that impacts would be at right angles to the face of the jetty. Was there not some risk, in practice, of tankers approaching somewhat obliquely, so as to cause a glancing blow and therefore give the fender posts a tendency to twist and possibly to bind in the guides? Had any trouble of that sort occurred?

127. Could the Authors say if the material used for the friction guides had proved satisfactory in the particular conditions?

Mr G. L. Hargreaves (Ministry of Public Building & Works) said that if the information was available, he would very much like to know the design coefficient of friction between the phosphor bronze plates on the piles and the resin material. He had personal experience of difficulty with piles of this kind held by the guides permitting movement in only one direction.

129. From Fig. 1, it was not easy to see exactly the precise setting of dolphin E in relation to jetty head No. 1, but it seemed to be about the same distance away from the jetty head as dolphin F was from No. 3 head and considerably further back. Both jetties might take a large tanker of about 27 000 tons, and the lead of the ship's head rope at jetty No. 3 would be about 45° from the centre line of the ship. If the same ship was lying against jetty No. 1, it would be merely a breast rope, almost at right angles to the ship's side. What particular reason caused dolphin E to be set so much further back than dolphin F?

Mr H. R. Boyce (Messrs Rendel, Palmer & Tritton) said he wished to refer to the piles and pile driving.

131. Dealing firstly with the head of jetty No. 3, the ground conditions found during the construction must have caused the designers many anxious moments when considering the strength of the raking piles and he would like to know at which level below the sea bed fixity was finally taken.

132. Some of the Rendhex piles were driven with open ends and some with closed

ends. The resistance to driving of the latter is primarily one of toe resistance, because the shoe of the normal Rendhex pile projects about $\frac{1}{4}$ in. beyond the perimeter of the pile and during driving the pile is like the Vibro pile upon which Mr Hiley based his formula. With the open-ended Rendhex pile the driving resistance is due solely to friction and so the Hiley formula would not necessarily apply.

133. Could the Authors say whether the mud level inside the open end pile was the same as the sea bed outside? Did the mud inside form a plug and therefore create some condition between the two just mentioned? Did the Authors have details of the soil characteristics? They had stated that the frictional resistance to extraction was 0.16 ton/sq. ft and he would like to know how this compared with the cohesive properties of the soil found by laboratory tests.

134. He hoped the Authors would give details of the driving of the precast concrete piles which had been referred to by Mr Roberts. Were the cracked piles withdrawn to see whether the cracks extended over the whole length of the pile? Were the piles really satisfactory after they had cracked during driving?

135. It would be helpful if a cross section of No. 3 jetty head could be provided because it was difficult to see how the loads from the lower waling beam were taken through the structure to the ground.

The following contribution was received in writing:

Mr S. P. Joshi (Senior Engineer, Sir Bruce White, Wolfe Barry and Partners (India)) wrote that the paper had been of considerable interest to him as he had been engaged on the design of a jetty in waters of similar depth and of similar tidal variations. This jetty was for a cement loading terminal on the western coast of India and the design arrived at was remarkably similar to that described in the Paper. The Authors were to be congratulated for presenting so clearly all the details of their design.

137. It was stated in § 20 that the ship's kinetic energy was assumed to be absorbed by four rubber fender units, two each at +19.00 and +2.00 levels. But for conditions of impact during low water, it would appear that the rubber units only at +2.00 level would come into operation for energy absorption.

138. The Authors stated that 50% of the ship's kinetic energy was assumed to be transferred to the structure, the other 50% presumably being absorbed by the deformation of the vessel itself, drag resistance of water mass in front of ship, rubbing of ship on fender posts, etc. Could the Authors say at what point of the jetty the ship was assumed to strike the fenders and at what angle? If the bow was assumed to strike the jetty, a further reduction in kinetic energy transferred to the structure would seem to be possible, depending upon the distance of the point of impact from the centre of gravity of the ship mass. If the ship was assumed to hit the jetty broadside on, there would be no such reduction in kinetic energy transferred to the structure, but the ship would be in contact with more than two fender posts and the load per rubber fender unit would be smaller.

139. Could the Authors give the maximum lateral loads for which the jetties were designed and the lever arms of these loads from the centre of each jetty?

140. The steel fender posts were not braced longitudinally and horizontal timber walings were not provided for the main berthing face, though these walings were provided for the rear barge berthing face. How had this particular system, of rubber cylindrical fender units in end-on compression with steel fender posts, stood up to horizontal glancing blows and longitudinal rubbing action of the ships while berthing? What was the coefficient of friction assumed in the design for assessing the vertical frictional drag force on the steel fender posts?

141. Would the Authors give the spacing of the fender posts along the length of the jetty and the detail at the top of the posts to hold these against outward movements due to blows at low water.

142. Was the filling of the Rendhex steel piles with concrete, as mentioned in § 39,

specified to increase the column load carrying capacity? Was the soil within the pile section removed prior to concreting?

The Authors wished to express their appreciation for the interest taken in the Paper, and for the very active discussion which took place. As the many questions raised were mainly on piling and fendering, it was considered preferable to answer them in groups rather than answer each speaker separately.

144. Dealing first with the questions on piling, and in particular with the Chairman's query in § 55, the Authors replied that the need for lengthening the piles had not exactly been a surprise as the boreholes had shown the ground conditions to be very poor. Pile tests should have been carried out within the site of No. 3 jetty head shortly after the contract started, but the Humber Conservancy Board and other parties had considered it to be unacceptably hazardous to shipping as it would have required the use of a floating crane for the construction of isolated stagings in very close proximity to tankers operating at the timber jetty. It was therefore decided to postpone such tests until the construction of No. 3 jetty head was actually in progress.

145. It was not thought at that time that the difficulties which might arise through poor ground conditions would be as troublesome as they eventually proved to be. Provision had been made in the Contract for extending the piling but not to the extent finally carried out.

146. Mr Williams, in § 86, had questioned the need for specifying a high degree of precision in the piling of the approach jetties. Some degree of tolerance was clearly desirable. With staging, it was quite possible to set the pile out and drive it quite accurately, but as soon as a floating craft was used instead of staging, much more tolerance was required and the question arose whether 6 in. would be sufficient. One still had to aim for perfection in setting the pile up, the tolerance being a safeguard against the many factors which could lead to the pile finishing out of its true position. It would seem that this tolerance would have to be based upon a knowledge of the driving conditions likely to be met to ensure that, given reasonable care, the finished pile would be acceptable.

147. As outlined in the Paper's introduction there were other reasons for using staging in preference to floating craft and it was questionable whether additional tolerance for the approach jetty piling would have altered the final decision to use staging.

148. In reply to Mr Boyce, § 134, a typical driving record for one of the cracked reinforced concrete piles would show a total penetration of about 40 ft, the first 20 ft of which would have been achieved by the pile settling under its own weight and the weight of the hammer; followed by a further penetration of about 15 ft at very light driving, before hardening up in the final 5 ft to reach the required 'set' on the boulder clay. Those which cracked were at the shore end where the bed level was high. Only hair cracks had been seen, and it was therefore considered unnecessary to extract any of the piles. Subsequent examinations had shown that the pressure from the superstructure had caused cracks to close and there were no signs of deterioration.

149. Mr Roberts had asked whether the Rendhex piles driven with a flat end or an open end showed any inclination to divert when driven in a rake. Those driven with a flat end were in the approach jetty where the rake was very steep, and no tendency to wander had in fact been observed. However, in several cases it was noticed that open ended piles driven at a rake of 1:3 tended to curve in the manner suggested by Mr Roberts in § 108. This was first noticed when a lantern which had been lowered into a pile to investigate a leaking seam weld showed the pile to be deflected by 18 in. at a depth of about 70 ft below its head.

150. In answer to Mr West, it was not possible to explain the rising of the test pile after one hour of loading. The pile tests had been faithfully recorded, but there may have been some movement of either the stagings or piles due to tidal action.

151. As to the strata within the neighbourhood of the test pile, it was unfortunate that boreholes were not taken in the vicinity of No. 3 jetty head before the Contract commenced, and that the nearest borehole was taken from the head of the timber jetty some 400 ft removed from the position of the test. The test pile was therefore driven in unknown ground, but the very soft driving and the quite remarkable take up in the ground afterwards were indicative of soft clay. A check test boring adjacent to the pile was given consideration, but as it could not be seen that it would be instrumental in making any economies in subsequent driving, the idea was not pursued.

152. The reason for testing with a shoe and then reverting to open-ended piles was that as the first stage of the test was on a minimum penetration it was obviously necessary to try to get the fullest value of the two parts of the bearing capacity of a pile; firstly, the skin friction which was obtained by leaving it as long as possible, although one could not afford a delay beyond six days, and secondly, the maximum toe resistance by the fitting of a pile shoe.

153. When it was known that the required bearing capacity could not be achieved on short piles, and that it was necessary to drive deep, it was then sufficient to drive the pile open ended as the consolidated plug of soil within the pile could be regarded as the equivalent of a shoe.

154. In answer to the questions raised by Mr Boyce in § 133, the Authors said that there was a draw-down of about 20 ft between the level of the mud inside the open-ended piles and the adjacent bed levels. At deep driving, the mud inside formed a consolidated plug as previously mentioned, and thereby created the intermediate condition suggested by Mr Boyce. The 0.16 ton/sq. ft frictional resistance to extraction was a fairly average value of the cohesive properties of the soft clays as determined from Laboratory tests on samples taken from the boreholes.

155. The depth to fixity of the piles had been taken as 20 ft below bed level, and in the case of the front row of piles, the concrete filling was reinforced to this depth in order to increase the pile stiffness and its column load bearing capacity.

156. In reply to Mr Joshi, § 142, the soil within the piles was not removed before concreting, and with the exception of the front row piles, the main purpose of the concrete filling was to prevent internal corrosion.

157. Mr Roberts' suggestion that the driving resistance obtained with finned piles did not necessarily indicate the ultimate bearing capacity was fully accepted by the Authors. It was agreed that had such a pile been tested after a period of rest it would probably have shown an increased bearing capacity due to the fins, but even so it was doubtful, in view of the particular ground conditions encountered, whether any saving made in the length of pile penetrations could outweigh the considerable cost of providing and welding the fins to the piles. It would, in any case, have been impossible to have forecast the required pile penetration and surface area of finning to give the required bearing capacity.

158. In reply to Mr McGarey, § 125, the Authors said that a tar composition was originally specified as a protective coating to the steel piles, but other materials had to be considered owing to the early failure of the tar. The eventual choice of coal tar enamel was determined by the very obvious need for a thick and durable coat which would eliminate the necessity for repetitive and extremely costly maintenance painting in tidal conditions. Pile surfaces were mechanically cleaned and internally heated before a priming coat and double coating of coal tar enamel were poured to form a total thickness of about $\frac{1}{4}$ in.

159. Referring to the question raised by the Chairman in § 56, concerning the fendering system, the Authors said that as the complete tidal range had to be covered in order to prevent any vessel of low freeboard from catching beneath the fenders, and as the depth of water was considered to be too great for fender piles, fender posts cushioned at two levels were thought to be the most suitable solution to the problem. Previously considered schemes involving concrete curtain walls draped with cylind-

rical rubber fenders, as outlined by Mr Lambert in § 79, were discarded owing to the hazard presented at low tide to ships of low freeboard.

160. The reason for the statement that the design of the jetty heads was largely influenced by the fendering scheme was that the berthing forces imposed upon the structure could only be assessed after the fendering scheme had been designed and its energy absorption characteristics were known.

161. In reply to Mr S. P. Joshi, the Authors said that for design purposes it had been assumed that the largest vessel would approach the jetty at an angle of 15° to the cope line and would strike the fenders at the end 'knuckles'. The maximum lateral load under these conditions was assessed to be 500 tons acting at a distance of 185 ft from the centre of the jetty.

162. At No. 3 jetty the fender posts were spaced at 10 ft 6 in. at the ends and at 21 ft 6 in. in the middle as shown on Fig. 6. At No. 1 jetty they were at a regular spacing of 13 ft due to the different berthing conditions. The Authors were unable to see any advantage to be gained by the closer spacing of the middle fenders as suggested by Mr R. A. Fisher in § 98.

163. Mr Joshi was correct in saying that for conditions of impact during low water, only rubber units at +2.0 level would come into operation for energy absorption, but this did not matter as the berthing of all but the smallest vessels took place at high water owing to the limited depth of the river channel.

164. In answer to the question raised by Mr Joshi in § 141, the Authors referred to the side elevation of the fender posts as shown in Fig. 5(b), in which it would be seen that the back plate of the rubber unit was bolted to the concrete beam. This arrangement prevented the top of the fender posts from outward movement due to blowings at low water.

165. Mr McGarey had questioned in § 127 whether the choice of materials used as fender guide plates had proved entirely satisfactory, but the Authors had to admit that several cases of failure had in fact occurred due to the bonded resin plates being insufficiently hard, especially as a result of the twisting of the fender post which caused local crushing of the guides. This point was coupled with the other questions raised by Mr McGarey and Mr Joshi as to whether glancing blows from vessels had given the fenders a tendency to twist. This had occurred with resulting damage to the guide plates in the end fenders which, as stated in the Paper, were the fenders generally struck by the large vessels. To remedy the situation, use has since been made of the fender transom beam for the formation of a much larger sliding guide system on the top of the waling beam for each of the fenders at the knuckles.

166. In reply to Mr G. L. Hargreaves, § 128, the Authors referred to Table 1, showing the coefficients of friction which had been obtained from laboratory tests from which it could be seen that the phosphor bronze/phosphor bronze combination was preferable. Unfortunately these test results arrived too late to be of guidance. Phosphor bronze plates have since, however, been substituted where necessary. The

TABLE 1

Material and condition	Coefficient of friction over 36 sq. in.	
	Static	Sliding
Phosphor bronze/linen based bonded resin (dry)	0.37	0.335
Phosphor bronze/linen based bonded resin (wet)	0.42	0.392
Phosphor bronze/aluminium based bonded resin (dry)	0.217	0.204
Phosphor bronze/phosphor bronze (dry)	0.152	0.147
Phosphor bronze/phosphor bronze (wet)	0.165	0.152

coefficient of friction assumed in the design for assessing the vertical frictional drag on the steel fender posts was taken as 0.30.

167. The cost of the jetty head fendering per linear foot of the jetty face as requested by Mr Williams in § 87, was given by the Authors as approximately £90.

168. The positions of dolphins E and F were determined by the shipping companies, but their distances from the jetty heads were not equal as had been suggested by Mr Hargreaves, and for any particular size tanker the mooring rope angle would in fact be practically the same at either jetty. The reason for dolphin E being set further back than dolphin F was that it was built while shipping operations at the timber jetty continued to take place, and it would therefore have created a hazard at that time if allowed to project riverwards of the jetty face line. Provided the mooring ropes were not crossed, a vessel could use either dolphin, and the Authors wondered why the shipping companies did not in fact settle for one dolphin only in a position midway between E and F.

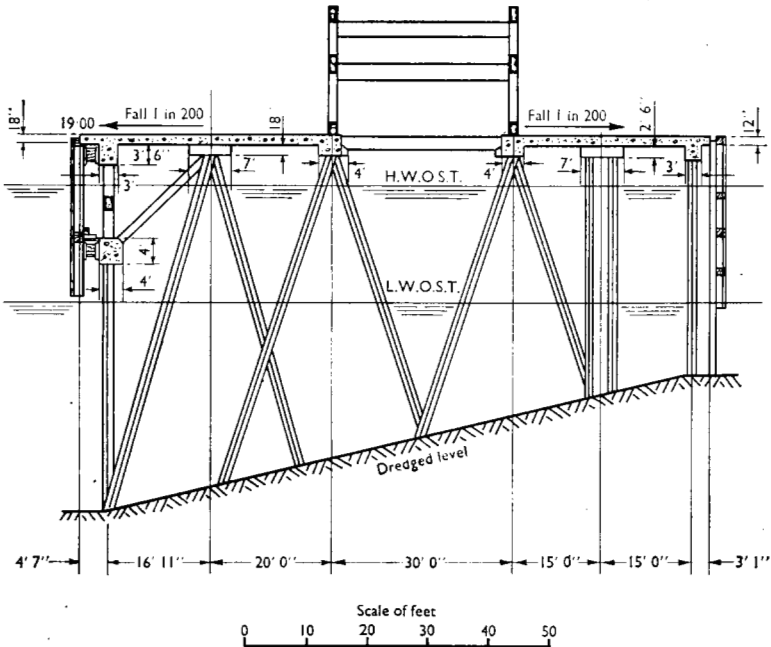


FIG. 15: NO. 3 JETTY HEAD—CROSS SECTION

169. The cross section of No. 3 jetty head (Fig. 15) had been supplied by the Authors in response to the request from Mr Boyce in § 135.

170. In answer to Mr Williams, §§ 87 and 88, the cost figures given in the Paper were the actual costs including all pile lengthening. The following summary of costs for each jetty head at deck level showed that the main reason for the disparity was the heavier section and closer spacing of piling at No. 1 jetty where a shorter jetty head had to cater for the same size of vessels as at the larger jetty.

	No. 1 jetty head	No. 3 jetty head
Total area of deck	14 050 <i>sq. ft</i>	31 100 <i>sq. ft</i>
Total cost to deck level, including fendering . .	£158 512	£287 646
Cost of piling per sq. ft of deck	£6 19s. 0d.	£5 4s. 0d.
Cost of structure and fendering per sq. ft of deck .	£4 6s. 0d.	£4 1s. 0d.
Total cost per sq. ft of deck	£11 5s. 0d.	£9 5s. 0d.

171. Finally, in reply to Mr McGarey's question in § 122, the following dates indicated the times occupied by the various stages of construction.

19 May, 1958	— contract commenced
30 June, 1958	— first piles cast
26 July, 1958	— first pile driven in approach jetty
10 August, 1960	— piling on No. 3 head completed
31 May, 1961	— civil engineering work completed on No. 3 head
10 August, 1961	— No. 3 head commissioned
18 September, 1961	— work permitted to commence on approach jetty to No. 1 head
9 November, 1962	— No. 1 head completed