*Discussion on Paper No. 6562**

Colombo Port development works

by

Reginald Duncan Gwyther, *C.B.E.*, *M.C.*, M.Sc., M.I.C.E.

and

Alfred Proom Humble, *M.B.E.*, M.I.C.E.

Mr J. E. G. Palmer (Messrs Rendel, Palmer & Tritton) said that the Paper spoke of the layout and construction of over two miles of deepwater quays within an existing protective shell of Colombo breakwaters, and if one omitted the two rather short lengths of quay, the coaster berth and the trawler berth, there remained 15 berths totalling some 10 375 ft, which was an average of very nearly 700 ft per berth. These 15 berths took six years to build, and Mr Gwyther may have worked out that this was more economical than building them all in, say, three years. They were economical, as Mr Gwyther had already pointed out, the 11 major berths complete with sheds and everything behind them costing a little under £450 000 each, which Mr Palmer thought was good. The blockwork, as described by Mr Gwyther, should give absolutely no maintenance trouble for the next hundred years. Another advantage of the design adopted was the ease with which the services trench could be fitted in at the back, and how very simple it was to provide the supports for the rear crane-rail. The photographs shown in the Paper indicated that an extremely fine looking harbour had been produced.

118. Looking at Fig. 15, the general view, and judging by the very great number of vessels at the moorings, it could be assumed, he thought, that at least half the trade of Colombo must be handled by lighters, and on that basis, and taking the total trade imports and exports together as about 5½ million tons a year, half of that, 2¾ million tons, gave something like 180 000 tons per berth per year, which was good going. But if one had the detailed figures for the bulk traffic, such as the oil, it might well be that those figures would have to be modified.

119. Among the most interesting features of the Paper (certainly of very great interest to Mr Palmer) were the alternative schemes which were produced at an earlier date to develop inside the shell of the breakwaters; and, with considerable deference to the firm's illustrious forebears, he thought that it was very fortunate indeed that the schemes of 1905 and of 1916 had not been carried out; he felt sure that it would not have been justified to put in a lock entrance and an impounded wet dock in an area where the tidal range was only 2½ ft, unless, of course, there had been some special circumstances. The Authors had mentioned the swell inside the harbour, and he supposed it was possible that there might be a certain number of days lost due to the range effect of long period waves; if so he would be very interested to hear about it.

120. On the whole he would have thought that the breakwaters would give good protection against ordinary storm waves, but he would not have put an additional opening between the north-west breakwater and the north-east breakwater. There was rather a surprising statement in § 77, namely, that "The rubble bank behind the north pier" (which presumably meant to the north of it) "originally had a smooth face, but because the seas swept over the pier a random rubble surface was substituted". He

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* *Proc. Instn civ. Engrs*, vol. 21 (April 1962), pp. 733–760.

was surprised that storm waves could have penetrated so far into the harbour, but possibly this was on rather rare occasions when there was a nor'-wester blowing, which would not be very often.

121. Could the Authors say whether the common-user pipelines had been generally accepted and were liked, or was it a fact that most oil companies would prefer to have their own pipelines?

122. As he had mentioned, Colombo harbour was a first-class job, and, reading the Paper carefully, it appeared to him that the construction had been completed without too many difficulties. There was one difficulty mentioned, namely, that there had been trouble with the cofferdam at the southern end of the Queen Elizabeth quay, and he understood that the reason for going in for cofferdam construction was in order to expedite the job. Would the Authors say whether it did expedite the job or not?

123. It would also be of value if Mr Gwyther would say something about his "Colcrete" pile foundations, and what the specification was, and whether it proved a success?

124. He was glad to hear that the contractor was present at the meeting. He had been astonished to read that the contractor had originally planned to do slice work construction by means of a floating crane. Surely the whole point about slice work was that it could be quickly and economically built, travelling forward as one went along, and in fact most of the work was done this way, after the first monsoon. He was delighted to see that the contractor had copied the idea that Mr Palmer had used at Haifa, namely, constructing a central abutment in horizontal blockwork and then supporting two cranes on it, starting off the slice work in opposite directions, which speeded up the job.

125. He could not help wondering in a case like this how he would have laid out these two miles of quays if given the job to do himself. Looking carefully at Mr Gwyther's lay-out, and in the light of the explanations given by him as to the commercial development being at the southern end of the harbour, he would have said that the Authors had tried as far as they possibly could to keep to the margins of the area instead of, for instance, drawing one long continuous quay straight across, which would have been more economical. He would himself certainly have lengthened the Delft pier in order to get four 750-ft berths in, and he would also have tried to widen the reclamation areas in order to get, wherever possible, a certain amount of open storage area behind the service roads.

126. In the case of the Prince Vijaya quay there was no open storage area at all, possibly because it was originally intended to be a coal depot and possibly also rather a wet area in the north-east monsoon. In the case of the Queen Elizabeth quay there was a 52-ft width behind the service roads in front of the Customs wall. That could have been considerably widened without any very great increase in cost.

127. Finally, he had already mentioned the "finger" pier, the Delft pier, which was at the moment 425 ft across from the west face to the east face, and he thought this could easily have been made 625 ft across, unless there was some other reason of which he was not aware.

128. Once again a most useful Paper on harbour works had come from Coode and Partners.

Mr N. N. B. Ordman (Divisional Engineer, Port of London Authority) said that his comments would be confined to the subject of transit sheds. He had learned from the Paper that the number and dimensions of transit sheds were determined by the Port Commissioners. The consulting engineers may well have thought this was rather fortunate, because the assessment of transit shed capacities from scratch could be a very arduous and tedious business.

130. If one asked an operating officer what his requirements were for transit shed accommodation on a projected berth his answer might well be, "I want the biggest shed you can give me, entirely free from internal columns and with as many doors as you can

get in the perimeter, and each door to be as wide as possible". This statement of requirements was in fact a very objective one from the operating officer's point of view, but it was not very helpful to the planner who had to devise some sort of logical approach and to set himself some planning criteria.

131. There were three criteria upon which one might base an approach to assessing transit-shed capacity, and this assessment was one of the key subjects in the design of a general cargo berth.

132. The first two criteria related to an economic assessment of the over-all project and availability of space. These were the sort of criteria which applied to any job. In relation to the assessment of transit-shed capacity they formed the limiting circumstances: they gave one the upper limit under which one had to work, and it was necessary to get closer to the practical requirements. This led him to his third criterion, which derived from the fact that in a berth it was the construction of the quay wall, and a proportion of the cost of the dredged approach, the breakwaters, and in some cases an entrance lock, lead-in jetties, etc. which constituted the most expensive element. Therefore it was reasonable to provide shore facilities, which included transit sheds, such as would provide the greatest exploitation of the quay wall.

133. If this were accepted as a reasonable planning approach the next step was to devise a method of measuring this exploitation. This could be measured in terms of berth occupation, i.e., the percentage of the total available time that the berth was used by vessels actually loading and discharging, not simply lying out. This was an important distinction, particularly in ports where there was considerable pressure on port authorities to permit vessels to lie up at berths when they were not actually loading or discharging at them.

134. What was a reasonable maximum percentage berth occupation to aim at? The figure he had taken was 70%. It was possible to exceed it and it frequently was exceeded, particularly when considering regular liner runs, but those who were familiar with queueing theory would know that 70% was in fact a high target figure to aim at for a facility like this. Having accepted this sort of basic criterion there was an over-all consideration which affected all three criteria, and that was the development of future operating methods which might not be clearly forseeable at the time the planning took place. Assuming that future operating methods would not eliminate the need for transit sheds (and this was not necessarily a valid assumption), then the provision for the future could be summed up in one word, and that was *flexibility*. This implied the provision of ample space for extension of premises—a feature which was lacking in some parts of the Colombo Development Plan—and also the avoidance of built-in specialized features, particularly in general cargo berths, the removal of which at a later date would be expensive and might render the facility ineffective.

135. They still had not quite got to grips with the assessment of capacity and an approach Mr Ordman had found very useful was the operational research technique known as simulation. Here a representative period, which might be months or a year or two, was selected and the vessels which actually used the dock during this period and were of the type (or even the particular vessels) which it was anticipated would use a projected berth, were examined. Data were amassed concerning these vessels, such as the tonnages they carried for each journey, the times of arrival and departure, stowage factors, types and derivations of delays, times for customs clearance, and many other relevant factors. Once these data had been amassed and analysed an exercise was carried out with the assistance of experienced operating officers which comprised in the first place drawing up a berthing programme aimed at high berth occupation—70% or so. The exercise then went on to simulate on paper the discharging or loading of these vessels successively over the whole representative period day by day. Thus a day to day statement of the hypothetical tonnage build-up in a transit shed was obtained. The exercise also derived maxima, but planners were not particularly interested in infrequently occurring maxima; day to day fluctuations were very much more interesting

because they enabled one to arrive at a level of capacity which it was reasonable to provide.

136. It was then necessary to translate the capacity from tonnages to floor area, which was done by recourse to stowage factors, allowances being made for gangways, sorting areas and so on, based on experience of the type of equipment it was proposed to use on the berth. These simulations produced other interesting information, such as the number of lorries and the number of rail wagons that had to be accommodated on the berth at any one time and the need for ancillary accommodation, warehousing, hazardous goods storage, security storage and so on. He had found this to be a very useful approach to what was an intractable problem.

137. With regard to the transit sheds at Colombo, he had noticed that they had adopted a standard height of 24 ft clear headroom. He found it extremely difficult to decide what was the optimum height for a transit shed, so much depended on equipment and operating methods. 24 ft was perhaps rather higher than that which was normally applied in transit sheds for general cargo and he wondered if the Authors knew why it was decided to use this height in Colombo. The widths of the sheds varied. On the Prince Vijaya quay the width was 90 ft and on the Queen Elizabeth and Delft quays the sheds were 110 ft wide. This variation might well have been dictated by available space, but if there were operating reasons he would be glad to know about them.

138. There was a statement in the Paper that the shed was clad with asbestos cement sheeting. He took this to mean that asbestos cement sheeting was used for the roof cladding and not for wall cladding. An excellent material in its place, it was rather too fragile for wall cladding, particularly on the quay side, where, even in roofs, it was rather vulnerable to damage.

Mr D. P. Bertlin (Consulting Engineer) referred to the ratio of length of quay to width, and the length of the berths at the Delft pier. He thought, from experience, that it was very important indeed to have adequate space behind the quay, though in many cases, owing to site restrictions, this width was severely limited. With the increased use of mechanical appliances and the intensive use of berths, surely this width should be greater than that adopted at Colombo? Personally, he would have liked an apron of not less than 65 ft in width, and preferably 80 ft or more, and a transit shed 120 ft wide with generous road and stacking space behind, probably of a minimum width of about 120 ft. This worked out at about 300 ft. With two berths back to back one might allow 560 ft, allowing for common road access. The Queen Elizabeth quay was in agreement with these figures, though perhaps a wider apron would have been preferable. The Prince Vijaya quay seemed to be unnecessarily cramped, as Mr Palmer had pointed out. A very similar pier which had recently been built was that at Tema, where the width was 490 ft. Of course, this depended on the cargo handled and the proximity of the warehouse and other stacking space. The Authors might like to comment on this point.

140. Mr Bertlin said that he had visited Colombo three or four years ago and had had a look at the harbour. At the trawler harbour he had noticed that there had been considerable leeching of the hearting through the armouring which caused subsidence of the central portion of the breakwater. The only obvious method of curing this seemed to be to have a new filter layer and put more armouring outside that again. This of course, was a very expensive solution and he wondered what method had, in fact, been used.

141. Another point which was not referred to in the Paper but which seemed an interesting idea was that of placing bollards well above the quay level on the Queen Elizabeth quay. There did seem to be obvious difficulties in this, and he wondered whether this was a success in practice.

142. Mr Bertlin also thought it might enhance the value of the Paper if more details could be given of the geological strata and the borings which were taken during the site investigation.

M. G. M. le Bel (Contractor, C.I.T.R.A.) thanked the Authors for the very kind appreciation they had made concerning the operations of his firm.

144. His firm had employed a force of about 1200 to 1600 Ceylonese labourers on the job. They were mostly common labourers, but there was also a good deal of skilled labour, mainly in the workshop. Despite some difficulty in finding local supervision, several Ceylonese engineers were used throughout the works, one of whom had been a very good engineer. The supervision was supplied by a force of about 45 to 50 Europeans: engineers, foremen and skilled labourers.

145. One of the characteristics of this work, which entailed a good deal of foundation work under water, was the necessity to have divers, and there were permanently about 12 divers on the job, working on a two-shift basis.

146. Ceylon had benefited by this intense training of its labour, and at the end of the job there were quite a number of labourers who had become skilled and had even acted as foremen. They were in some cases re-employed on other jobs afterwards.

147. Owing to the magnitude of the works and the short time for completion the contractors had had to bring on to the site a considerable amount of important construction plant. There had been two or three shovels of about 2 yd capacity for the quarrying operation, which took place some 16 to 20 miles away. The appropriate crushing plant was provided so as to make all the aggregates required, and on the harbour there was a batching plant and a concreting station producing about 50 yd/hour. The output of concreting was very near to 400 cu. m or 500 cu. yd a day. The block yard had entailed many temporary works as well as the settings of rails for the gantry cranes, which Mr Humble had mentioned in his opening remarks.

148. On the sea side the contractors had to carry out a good deal of dredging. It had been necessary to dredge all the foundations for the quay walls, and they had been helped by a second dredger which was brought for reclamation later.

149. There were about eight barges of 60 to 200 tons, two tugs, one of 350 and one of 450 h.p., and three hopper barges for the spoil. It had been characteristic of this job that the plant was mostly brand new and amounted to over 25% of the value of the job. Indeed, it was impossible for a contractor to depreciate such plant entirely on a job of this magnitude. This big plant was costly to maintain and costly also to transport, and the difficulty was to find another job on which it could be used.

150. The answer for the block setting problem had undoubtedly been the Titan cranes. They were designed for the job and were entirely suitable for it in practice. They were diesel-electric in order not to depend on any exterior source of energy. They were on tracks which were fitted on a kind of frame. There were three sets of such frames and one was taken from behind and put in front when the crane was at the end of one section. These tracks were supported by the quay wall proper on one side but on the other side concrete blocks were temporarily placed because the width of the quay wall on top was too narrow for the gauge of the cranes. Those blocks were picked up behind and put in front in order to make the crane advance. These two cranes had been very useful but it had been very difficult to use them again.

151. The work had been very interesting and, from the contracting point of view, he felt that the inclined slice work was a good way of constructing quay walls, building them by land methods in order to avoid the hazard of the swell and the uncertainty of floating equipment. But with vertical blocks the stability was questionable and unless they were very big blocks indeed there could be difficulty. In this case the slices were supported one by the other and gave a good stability by friction and there was no danger of a slice coming in front or behind and falling down. His firm had had experience in other parts of the world with vertical blocks, weighing 120 tons in Casablanca and up to 400 tons in Algiers. Those blocks were very large and offered a good stability, but they had to be built using floating cranes.

Mr G. L. Hargreaves (Admiralty) said that he had happened to be in Ceylon during the more interesting period of the construction of the works described in the Paper, and by courtesy of Mr Humble he was given opportunities of inspecting the work and hearing of the various reasons behind the forms of construction and different aspects of design.

153. His first impression of the Paper was one of regret that it was not in fact several Papers, because it was a classic engineering job on a large scale, and the blockwork alone would have made a subject for a useful paper.

154. His primary interest at present was in the conditions inside the harbour, and he drew a parallel between one of the Admiralty harbours at Gibraltar, which was very similar in lay-out and orientation to Colombo. The main axis lay north and south, and the proportions of the harbour were roughly similar. Like Colombo, it was protected by three breakwaters and had two entrances. Unlike Colombo, it was tucked inside Algeciras Bay, which protected it from the worst Atlantic swells and seas, but none the less quite a sizeable sea could wheel round the south of Spain. The maximum height of wave reported attacking the breakwater was of the order of 12 ft. In most cases it was considerably less than that, but 12 ft had been mentioned. The Authors had not mentioned in the Paper the height of the waves that attacked Colombo but he understood them to be in the region of 16–18 ft in monsoon conditions. Apart from this, both harbours had the same history, starting with an open roadstead used by shipping, and the engineer, when called in to provide more sheltered water, had built walls. He had to leave holes in the walls for ships to come in, and the sea got in through the same holes causing a certain amount of disturbance inside, but the last stage was very much better than the first, so everyone was satisfied. Later, as in the case of Gibraltar, the land inside became extremely valuable and the unfortunate engineer was called in again to reclaim some of the sheltered water and to build vertical quay walls against which ships could be berthed; at one and the same time, to reduce the water area, to make it deeper and to provide more reflecting surfaces.

155. At Gibraltar this process had resulted in a marked deterioration of conditions inside, so that he had seen reports of ships being damaged while lying alongside and even a case of a large ship breaking her berthing wires and taking off from an alongside berth. That was in a sheltered harbour which was only exposed at the most to 12-ft waves outside the entrance.

156. He believed that in Colombo somewhat similar conditions were obtained. The navigators of some of H.M. ships had stated that on occasion lighters could not lie alongside, and he had seen quite heavy swells breaking at the south-eastern end of the harbour among the shallow-water berths. In § 77 the Authors had mentioned seas breaking over the northern pier of the oil wharf, so it appeared that in Colombo, as in Gibraltar, quite a sizeable amount of wave energy could penetrate the harbour and proceed to run riot. In Colombo the Authors had provided something like two miles of new vertical faces and they had dredged out between $\frac{3}{4}$ and $1\frac{1}{2}$ million yards of spoil, most of which must inevitably have been in the shallow water areas of the harbour. He would be very interested to know whether any measurements had been taken before and since construction of the works to find out what effect the works had had on sea conditions in the anchorage, at the alongside berths and in the shallow-water berths to the south-east. If, in fact, the answer was that nothing much had happened, he thought that Colombo would deserve still further study to find out how this desirable state of affairs had been maintained.

157. Mr Hargreaves had never been concerned himself with the construction of blockwork walls, which he regarded with a certain amount of awe and lack of understanding, although he had been concerned with almost every other sort of wharf structure. He was interested in the form of construction adopted for the Delft quay and the coaster berth, where a heavy deck was carried on cylinder or pile supports, while below the deck there was a sloping rubble bank. In these two instances the bank did not come up to top water level but if that form of construction had been adopted and the rubble bank brought up to top water level, the amount of reflexion inside the harbour

would have been somewhat reduced; he would be very interested to know what considerations decided the design and made the consultants select blockwork walls instead of the form of construction they themselves had adopted in the two cases mentioned.

158. The fishery harbour seemed to be a neat little harbour exposed to practically the full monsoon swell. The swell coming from the south-east, according to his recollection, wheeled slightly on reaching the 10 fathom line a few miles outside Colombo, and he thought that the fishery harbour could gain only little protection, if any, from the main harbour. What size of blocks had been used on the breakwater, how had they behaved under assault by the sea; how much maintenance, if any, had been required since the works were completed?

Mr D. H. Little asked the Authors how much settlement occurred in the sand filling. It was quite common practice to build walls out in an estuary and then fill in behind them as shown in Fig. 9. He knew of two naval dockyards like it. One of these had been filled with rock, and where there was a maximum depth of 60–70 ft there had been 2 ft of settlement in 30 or 40 years. Bollards which had stood 2 ft above the ground could hardly be seen when he went there 30 or 40 years later. In the other silt had been pumped ashore as the filling and in both these yards all major buildings were still piled 40 years later.

160. Still referring to Fig. 9, quite a large shed was not piled at all, and in Figs 5 and 7 piles were shown under the buildings but they stopped short. Was this a drafting error or did the piles in fact just go down and stop short of any solid filling? It might be that this sand filling had instantaneous settlement properties, but he still wished to ask the question.

161. The other question he wished to ask referred to fendering. Were these solid walls fendered in any way at all? It rather looked as though they were not and if the seas were as rough inside the harbour as had been suggested, vessels must get rather badly knocked about pounding against these apparently solid walls. Personally, he was all in favour of that, but did not know whether the shipping people were!

162. Block walls seemed to be a peculiarly British institution. At £165 per ft and 45-ft high they were surprisingly cheap. He understood that this was just the bare bones of the wall, with no filling behind it and no services; in fact, these walls were particularly free of any sort of services at all: no cranes, railway or anything, but just a plain wall on which a car could run about, and there did not seem to be any other facilities. A plain wall like that at £165 per ft run was cheap. He ventured to suggest however that a flat slab wall or relieving platform type of wall would be 10–15% cheaper, and it would appear from Fig. 9 that such a platform would be continued back beyond the building line and so have carried the fronts of the buildings without having to sit them straight on sand.

163. Referring to the remarks of Mr Hargreaves, he supposed that with an open wall the oil dock would not have been usable half the time, because the north pier seemed to act as an inner breakwater. That might be one argument against the open wall but he was quite certain that, in spite of the cheapness of these walls, a simple pile structure would have been considerably cheaper. If one could get at least a minimum of 4 ft of excavation, as there seemed to be here, then a pile driven into this 4 ft of soft stuff onto rock would be quite satisfactory.

The following contribution was received in writing:

Mr A. N. S. Kulasinghe (Deputy Chief Engineer, Colombo Port Commission) wrote that the Authors were to be congratulated on putting together in the form of a Paper the historical background of the Development of the Port of Colombo from its early times and also for giving a general idea of the major developments which took place in the 1950s. One of the main purposes of a Paper of this nature was, he believed, to bring to the notice of practising engineers the various problems that had to be faced during the execution of the project and how they were solved. He thought that this aspect had not been given sufficient consideration in this Paper, and, therefore, certain aspects of this work are brought out in the following brief comments:

165. It was stated in § 2 of the Paper that "The pier was later cancelled and a marginal quay substituted". It would be helpful if the reasons for this change could be given, along with a comment as to whether the change resulted in an improvement, taking economics, as well as the usefulness of the quay and ease of operation, into consideration.

166. In § 3 it was stated "In order to expedite the construction of the terminal building the landward quay was constructed in cofferdam". The construction of the cofferdam had to be done under very difficult conditions and therefore certain delays also were inevitable in the completion of the cofferdam as originally scheduled. It would be useful for record purposes if it was stated whether the construction of the cofferdam finally achieved its purpose, that is, whether it was possible to construct the terminal building in time and whether the construction of the cofferdam itself contributed to the early completion of the terminal building.

167. At § 10 it was stated that "all transit sheds were of fabricated structural steel work". The cost of these transit sheds has also been given in Table 3. It can be seen that the costs of the transit sheds per sq. ft have varied from Rs.29·50 to Rs.40·50. This figure apparently does not take customs duty into consideration as the materials supplied under the contract were free of customs duty. These rates are considered to be very high when compared to the cost of similar buildings constructed in the Port and elsewhere. These buildings suffer another disadvantage in that they are subject to severe corrosion due to their proximity to the sea and the high humidity in Colombo. This results in considerable expenditure in maintenance which had been over £1000 per year per shed. Considering the high cost of steel in Ceylon and the severe corrosion that steel is exposed to, it would have been expected that more suitable construction materials like reinforced concrete and prestressed concrete would have been used in the construction of these sheds. The contractors themselves had had considerable experience in construction of large structures in prestressed concrete and very good aggregates were also available in Ceylon for the production of high quality concrete. At the time these buildings were constructed high quality concrete (in prestressed concrete structures) was being produced in the Port itself by the Chief Engineer's Department. It is therefore difficult to understand the decision to use expensive structural steel work in the construction of the sheds when the conditions were more favourable for construction in concrete. As an illustration, details of a food warehouse—100 ft span × 410 ft long and 24 ft clear height, constructed in 1955/56 are given in Fig. 19.

168. This building which is very similar in dimensions to the transit sheds constructed under the Port Development Contract, cost less than Rs.20 per sq. ft., inclusive of customs duty and departmental overheads, which had to be added, as the cost was debited to a commercial account of the Food Commissioner. The maintenance of the building has involved only colour washing it once in about 2 or 3 years, and the annual maintenance cost has therefore been less than Rs.1000 when compared to over £1000 for the transit sheds constructed in structural steel work.

169. In § 27 reference was made to the floating boom closing the entrance to the oil dock. It has been found in practice that opening and closing this boom under normal operating conditions has involved so much difficulty that this boom has not been used for a long time. The flexible pipe connexions between the sections of the pontoons have also a very short life and the Port Commission is now investigating the possibility of using a type of boom which can be more easily handled under operating conditions.

170. Paragraphs 41 and 42 give a short description of the Fishing Trawler Harbour. The design of the moles is given in Fig. 10. It has been found that the section of the mole is insufficient to withstand wave action at this site, and there have been heavy losses of armour stone and even a part of the core, due to this reason. The Port Commission has had to spend a considerable amount of money in maintaining the moles which involves the replacement of a large percentage of the armour stone lost by wave action.

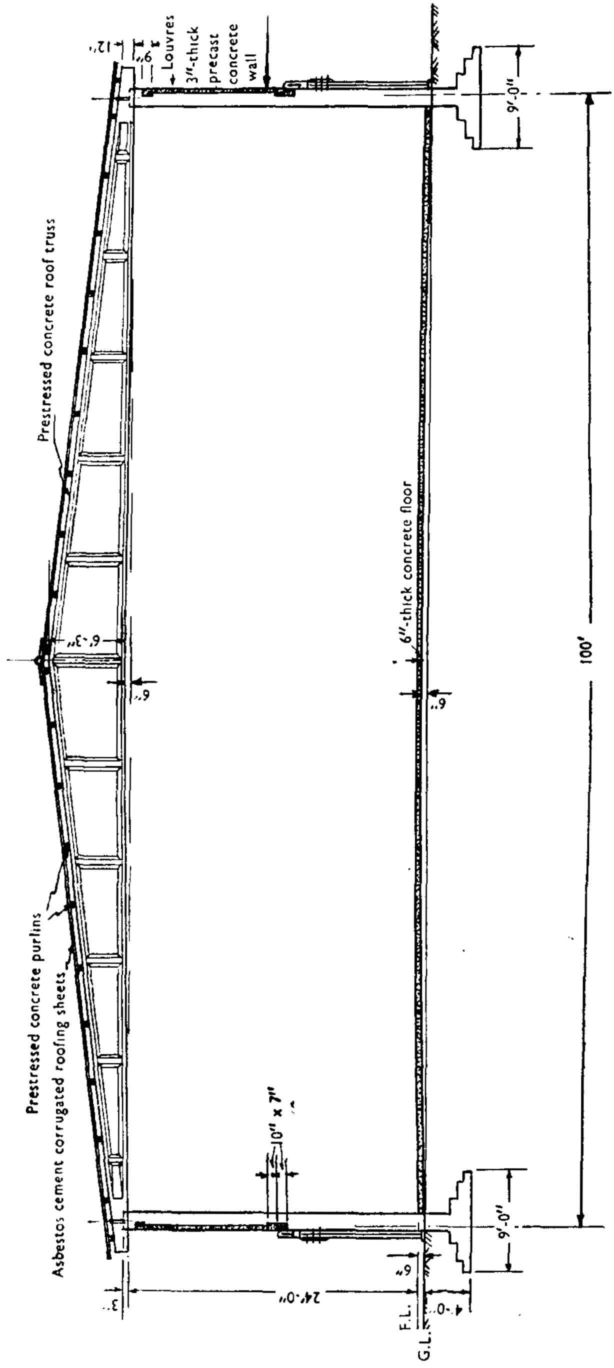

FIG. 19: CROSS SECTION OF WAREHOUSE AT CANAL YARD

It will be interesting and useful for future designs if the characteristics of the design wave are given.

171. There has also been another difficulty which has come to light at the Queen Elizabeth Quay shortly after it was commissioned for use. Loss of the filling behind the quay wall has occurred through the joints of the blockwork and certain areas of the quay surfaces had been undermined leaving only the surface crust. This loss of material was so serious that a lorry riding on the apparently sound surface partly disappeared into the cavity below. It will be useful if the normal remedial measures for such an occasion are given. It has been found that satisfactory remedial measures that the Port Commission had to undertake involve a large sum of money. Some action to avoid similar failure could be useful.

172. In § 98 the cost of the terminal building was given as Rs.2·848 million. The cost per sq. ft of floor area therefore works out to Rs.82 approximately. This cost is considered very high for a building of this type and it would be useful if the Authors could comment on the reasons behind the unusual high rate.

173. What was the cost of the cofferdam and is it included in the Rs.2·848 million? The greater portion of the cost of the cofferdam, if not the whole amount, should be debited to the cost of the terminal building as the cofferdam was built to "expedite the construction of the terminal building".

The Authors, commenting on Mr Palmer's remarks, did not consider that the 15 berths could have been built in three years in the early '50s, particularly as it took some 18 months to develop the quarry and organize a blockyard to produce over 1100 blocks per month.

175. The lock entrance shown in the earlier schemes of 1905 and 1916 was no doubt intended to enable the swell, which at times varied from 2 to 4½ ft, to be excluded and so avoid the ranging of vessels when loading or discharging cargo.

176. On comparatively rare occasions, waves of sufficient height to cause difficulties at the oil dock might occur, and the substitution of a random rubble finish in place of a smooth slope to the bank along the north side of the north pier of the oil dock gave satisfactory results.

177. At Colombo, common-user pipelines deal with incoming oil which is pumped to the tank farm at Kolonnawa. The oil companies have their own bunkering lines from Kolonnawa to the harbour, but bunkering in the harbour is done mainly by barge, though one oil company had installed bunkering lines on the Prince Vijaya Quay but these were not connected up. As it is understood, the Government now largely control the trade, the present position is unknown.

178. Despite difficulties the cofferdam did expedite the work, particularly the construction of the terminal building. Excavation by dredging, without a cofferdam, would have removed much ground from the site of the terminal building and would, due to the presence of the large boulders, have probably taken longer. The cofferdam cost Rs. 2 537 858, but credit for the steel piling and frames recovered, would reduce this cost to about two thirds though we do not know what was allowed. The terminal building was not debited with any part of the cost of the cofferdam.

179. The colgrout process was that developed by Messrs Gammon. A 12-in. internal dia. tube with shoe was driven to a set of 1/10 in. with a three ton hammer dropping 2½ ft, within which a reinforced cage with six main bars ⅝ in. in diameter was inserted, and the tube filled with 2 in. size stone, from which all fines were removed. The stone was then grouted from the bottom upwards with 1–2 cement colgrout and the tube withdrawn. The concrete pile, so produced, was required to take a load of 15 tons and proved satisfactory under an actual test load of 35 tons.

180. The layout of the quays at Colombo, referred to by Mr Palmer and Mr Bertlin, differed from the more usual arrangements, in that only at the Prince Vijaya Quay and the west quay of the Delft Pier were there any rail tracks on the apron. Generally the rail tracks were at the rear of the sheds. Such being the case the apron widths of 45 ft

at the Delft Pier and 50 ft at the Queen Elizabeth Quay were considered to be adequate. Generally speaking, however, the Authors like to provide a 66-ft wide apron.

181. There was no demand for extensive open storage at Colombo. Apart from coal and oil the chief imports are rice, flour and sugar, while the main exports are tea, rubber, coconut and coconut oil.

182. The width of the Delft Pier, which was referred to by both Mr Palmer and Mr Bertlin with suggestions that the width of 425 ft might well have been increased to 560 or even 624 ft. The width and alignment of the Delft Pier had to conform with the general principle of leaving the maximum number of buoy berths available, in both monsoons, for the large number of vessels calling at the port, possibly only for a few hours. These vessels must of necessity use the buoy berths, which are indicated by the dots on Figs 1–4.

183. Mr Ordman had referred to the problem of shed capacities which the Authors agreed was fortunately determined by the Port Commissioners. The Prince Vijaya Quay was for some time used for handling scrap iron, and the sheds on this quay were used later, for some considerable period for storing rice and sugar. The sheds at the Delft Pier were designed for handling rice and general cargo, whilst large passenger vessels and general cargo vessels both berthed at the Queen Elizabeth Quay. The intention of the Port was to give better facilities for the landing passengers and so encourage visitors to the island. These large vessels usually loaded tea while at the berth, which is regarded as a valuable cargo. Actually the width of the sheds on the Delft Pier and on the Queen Elizabeth Quay had both been reduced from 120 ft to 110 ft by the Port Commission on the grounds of economy.

184. The 24-ft height of the sheds was suggested by the Port Commission and was determined to a great extent by the required 18-ft height of the doors, to which a further 4 ft should be added to allow room for knee bracings. Brick side walls extended up to $8\frac{1}{2}$ ft above the floor level and the cladding above this wall was of asbestos sheets.

185. The Authors were interested to learn that the expenditure on maintenance of the sheds had been over £1000 per year per shed. The choice of steel sheds was made by the Port Commission and zinc metallization was applied to those parts of the steelwork of the sheds, on the Prince Vijaya Quay, which were not accessible for painting at a later date but this metallization was omitted from the sheds at the Delft Pier and Queen Elizabeth Quay by order of the Port Commission.

186. In the Author's recent experience a shed 400 ft by 150 ft constructed in precast reinforced concrete in 1960, showed a saving over a similar shed constructed in steel of 14%, when stresses of 1400 lb/sq. in. for concrete and 20 000 lb/sq. in. for steel bars were accepted. It is doubtful, however, whether such saving would have been achieved in 1950. The sheds in question were three bay spans.

187. Mr Bertlin had Mr Kulasinghe made reference to the trawler harbour and to the fact that there had been some draw down of stone on the seaward slope where the wave wall turned along the extension arm. The contractors were pressed by the government to commence work on the reclamation in the middle of 1954, against their better judgement to delay construction until late October, after the south-west monsoon. Difficulty was also experienced in obtaining the size of stone required from the quarry which at that time was producing comparatively small rubble for foundations and stone for concrete. There was a loss of rubble due to storms in the summer of 1955 but this was made good at the time. During the first few years after the construction some draw down of the stone facing would occur and replenishment would be necessary.

188. Owing to the difficulty in obtaining large stone for armouring after the work had been completed, it was suggested that stone in nets, or blocks made of concrete, should be assembled on the top of the bank and left to be drawn down by the sea. The Authors did not know what was sone but delay in carrying out repairs would lead to a major work eventually.

189. Attention has been drawn to the pillar bollards on the Queen Elizabeth Quay.

Although the placing of these bollards between the transit sheds would form an obstruction to the access to and from the apron they were provided at the earnest request of the pilots as an additional mooring facility during the south-west monsoon. Similar pillar bollards were provided near the oil dock but the Authors could not say whether they were used during the south-west monsoon.

190. The geological strata of the harbour could be described as sand and clay, and a hard material, generally known as kabouk, overlying rock which is encountered at a depth of 66 ft at the outer end of the Prince Vijaya Quay, 40 ft at the end of the guide pier and at depths below 70 ft at the Queen Elizabeth Quay.

191. The Authors were greatly interested in Mr Hargreaves' comparison with Gibraltar Harbour and the effect the vertical walls and deeper water had on conditions inside the harbour. As at Gibraltar, opinion differed widely as to the size of waves outside the harbour and it was extremely difficult to obtain measurements but an average maximum of 12 ft was accepted. Prior to the construction of the main mole for the fishing harbour, waves of 7 ft and 11 ft above datum had been recorded.

192. Local statements, based largely on opinion, gave the height of waves entering the harbour as from 5 to 10 ft, but the actual measurements showed that the average maximum was about 5 ft and this height was used in the model experiments referred to in § 36. In comparison with Gibraltar it should further be borne in mind that, due to the fact that there are normally 15 to 20 deep-sea vessels moored at the buoys, thus offering a series of moles, the waves entering the harbour are to some extent dispersed and/or deflected according to the number and positions of the moored ships. This no doubt is the reason for the somewhat wide estimates of the height of waves at any particular point. The Authors, however, do not consider that the construction of the quays has had any great material effect upon the wave action inside the harbour. This no doubt will be confirmed, or otherwise, by the Port Authority in the course of time.

193. The answer to Mr Little's question regarding fenders was that no fixed timber fenders were provided. At the Prince Vijaya Quay 10-in.-dia. tubular rubber fenders were later slung horizontally at approximately 3 ft above high water from fastenings at 12 ft intervals. On the Delft Pier and Queen Elizabeth Quay 15-in.-dia. rubber fenders, 10 ft long, were suspended horizontally by $\frac{7}{8}$-in.-dia. chain at alternate 18 ft lengths, as mentioned in §§ 99 and 100.

194. Both Mr Hargreaves and Mr Little had mentioned that a simple pile structure might have been cheaper. The problem with such structures is to support any depth of fill apart from carrying cranes and tracks on the apron, and a loaded transit shed. Within limits filling for back areas can be retained by sheet piling, but in the Authors' experience the cost of this type of construction is invariably greater than that with the simple wall.

195. Mr Little had asked how much settlement occurred in the sand filling. The sand was pumped direct from the suction dredger *Colombo* by means of a floating pipeline and in general there was no appreciable settlement. Ground tests were taken, as described in § 84, and piling was only required where some of the underlying mud had not been sluiced away before the sand was deposited. The piles shown in Fig. 5 were driven to a set as mentioned above.

196. Some loss of filling had been experienced behind the quay of the Queen Elizabeth Quay, as described by Mr Kulasinghe. To avoid this the backs and upper parts of the blockwork extending above low water were caulked and the filling placed while there was still an open end behind the quay for the tide to run in and out. This method proved effective at the Prince Vijaya Quay, Delft Quays and the Queen Elizabeth Quay, except apparently on a length between chainage 130 ft and 1100 ft which was ordered to be done quickly, and possibly the correct procedure has not been followed on this length.

197. Mr Kulasinghe's account of the difficulty in operating, and of the failure of the pipe connexions of the articulated floating boom with its fire-fighting equipment, was of

great interest to the Authors. Since that day the flexible type of floating boom, constructed of reinforced plastic, which is much more easily run in and out, has been introduced for containing oil spills. Whether any of these will be able to contend with the swell conditions at the oil dock, and provide the requirements for fighting an oil fire, is, the Authors gathered, being considered by the Port Commission.

198. The cost of the terminal building works out at approximately Rs. 82 per sq. ft of area, as Mr Kulasinghi had pointed out, but this figure includes for balustrading, plumbing, kiosks, counters, fittings and furnishings, amounting to some 31% of the total cost, so the figure is not, in the Authors' opinion, unreasonable.