The design and construction of the Ocean Terminal, Hong Kong

S. E. FABER, J. C. FABER & J. M. THOMAS

Mr S. E. Faber

I would like to mention the salient points which arose during the designs, first, to arrange for efficient cargo handling to ensure a rapid turn-round of the ships, second, to provide ample space for processing passengers and tourists, and thirdly, to provide amenities to attract shoppers and local residents.

88. In 1970 the records show 388 ships berthed at the terminal, made up of 103 passenger ships, 10 cruise liners, 254 cargo ships, and 21 container ships, these only for four months, as since then they have been using No. 5 wharf. Passengers recorded were 15 000, and there were 5½ million visitors. Cargo imported was 40 000 tons, and exported 280 000 tons.

89. One of the main difficulties in planning was that potential lessees, faced with a proposal which was new and to them rather speculative, were very slow in making up their minds what they wanted. We had therefore to keep the planning very flexible: even at the end there were still changes which had to be made. This was all in the superstructure, and it showed more clearly almost every day the advantage of the Contractor's design in separating the deck structures from the superstructure because it gave the clients several months longer in which to settle the final details of the letting.

90. It has proved very popular to local people, as about 115 000 persons visited the terminal each week.

Mr D. L. Pope, Bertlin & Partners

At one time I was employed by Taylor Woodrow on the construction of the Ocean Terminal. For someone who was concerned with this project at very close quarters on site, the day-to-day problems were very acute from my point of view. It is therefore very revealing to have a Paper like this which puts the whole problem into perspective.

92. However, the Paper compresses a large project into a short space, and I think that in one or two instances the Authors have erred on the side of being too concise. In particular, the question of the provision of independent foundations for the jetty deck and the superstructure which is stated in § 25 as having the following advantages:

(*a*) the client and the lessees could delay until the last possible moment decisions on the layout of the superstructure;
(*b*) the problems of differential settlement between the jetty and the superstructure would be minimized;
(*c*) the deck structure can be kept shallow and out of the tidal range.

93. The layout of the columns was determined in advance, and I would suggest that since the deadload must be a very large proportion of the load on the columns, it would only be a very small number of columns where the final design load was not known in advance. So this cannot really have been an important criterion.

94. So far as differential settlement is concerned, if the whole structure was carried on one foundation system, there would not have been any problem. However, by

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separating the two foundation systems in this way the differential settlement was, rather than being alleviated, certainly concentrated in the area between the deck level and the first floor level where a number of problems were encountered.

95. I think the main advantage is the possibility of keeping the deck shallow, but it would have been possible, I believe, to have raised the deck level slightly, or alternatively to have introduced composite or prestressed beams in the deck, thus cutting down the required depth of construction to spread the column loads to a group of adjacent piles.

96. In view of the problems which were encountered from settlement of the cylinders, I would like to ask the Authors whether they would use this method in building another structure of this type.

97. Were the telescopic passenger gangways successful? When I last saw the structure, these were not working successfully, and I believe there was a history of problems. Another question relates to the expansion joints in the superstructure. The vertical joints, I believe, were formed with expanded polystyrene and sealed with bitumastic seal. I heard rumours that the polystyrene was being eaten by rats and I should like to know whether this is true or whether any problems were experienced with these construction joints.

Dr J. H. Jellett, Past President*

I would like to know whether there is any problem with Customs in Hong Kong. The problem of meeting Customs requirements, to keep visitors, passengers and cargo strictly segregated throughout the process had a considerable influence on the design of the Southampton ocean terminal.

99. This project in Hong Kong is very much larger than the one at Southampton. There we did not have any problem of building our own foundations. We were on an existing quay, so that we were not concerned with the quay structure. On the other hand, we had a problem of feeding our terminal with the railway, which has not been found necessary at Hong Kong.

100. Like Mr Pope, I am particularly interested in the telescopic gangways and my heart rather bled for the Authors when I read the opening sentence of § 72. The ingenuity which ship builders have displayed in siting the shell doors of their ships at all levels, in all parts of the ship, at every possible angle, and fitting them with a variety of obstructions to the safe landing of the gangway is something that I do not think anyone would believe unless he had direct experience of it. We found it absolutely essential every time a new ship proposed to come to the ocean terminal for the first time, to send a member of the staff to visit that ship wherever it happened to be, and take the measurements of the doors for ourselves, because we never could get coherent information as to what sort of aspect the doors would present to the single point landing hook, which we found in the end the most satisfactory solution.

101. The Paper does not mention the material of which the Hong Kong gangways were constructed. At Southampton we employed aluminium, this being just after the war when aluminium was a fairly plentiful material, and also gave us a lighter structure for handling. On the other hand, a few years after the gangways went into service, there were the first early Comet disasters and the subject of fatigue in aluminium suddenly arose. We then took the precaution of removing from the gangway one or two members that had been subject to considerable reversals of stress in the course of normal usage and examining them to see if any fatigue was taking place. A certain amount had developed, but nothing that need cause undue anxiety on account of safety. However, I should like to know whether any such problem as that was met at Hong Kong.

102. We had a variety of problems in connexion with the operating equipment of the gangways which I am sure the Authors were fortunate to be saved owing to having

* It is regretted that Dr Jellett died before this contribution could be published.

built their terminal in rather more plentiful times. The first driving motors installed were quite unsatisfactory in their characteristics, but they were the only ones we could get. The correct motors were blandly offered to us by the manufacturers at 300 weeks delivery.

Mr G. H. Cochrane, Taylor Woodrow

I was closely concerned with the structural design of the Ocean Terminal. The Paper shows how structural design takes only a small part in the planning and functional design of a building of this nature, nevertheless I should like to enlarge upon one aspect of the structural concept—the arrangements made to accommodate thermal expansion and lateral movement of the building and pier deck.

104. The deck structure is assumed to expand and contract about its centre. Fig. 11 is an idealized picture of the pier deck, showing it in a contracted state. The majority of the supporting piles are considered to be of uniform length and effectively encastered within the sea bed and at their heads. Towards the Praya end, however, the free lengths of the piles reduce progressively, particularly where they penetrate the rock apron protecting the foundation to the Praya wall. In that region the piles were provided with 'pinned' head connexions. These piles then deflected in single bending as the deck moved, rather than double bending, and the pile wall stresses were thus maintained just within the allowable range. The anticipated total thermal movement was $\pm\frac{1}{2}$ in. at each end of the deck.

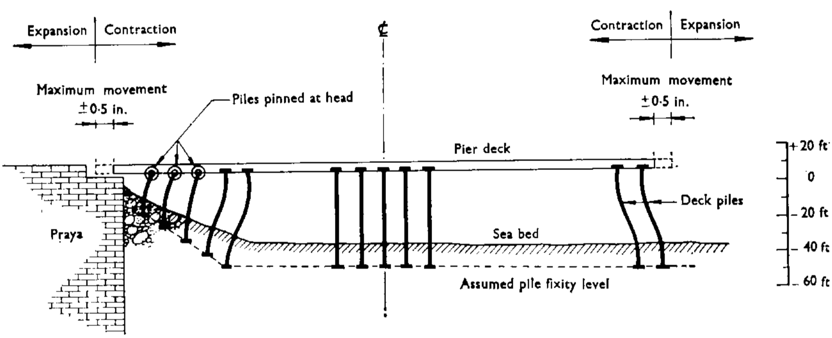

Fig. 11

105. The terminal superstructure was divided into six expansion bays as shown in Fig. 12a. In the four outermost bays, 3, 4, 5 and 6, the superstructure columns were restrained in position (but not in direction) by the pier deck, whereas in Bays 1 and 2 the columns passed through the deck, without any restraint. The effects of longitudinal contraction of both the deck and the superstructure are shown in Fig. 13. Under contraction conditions the columns and cylinders at the seaward end of the building are dragged shorewards by the deck, whilst the columns at the shore end become offset in the deck apertures. At frame No. 6, the expansion joint between Bays 2 and 3 of the superstructure, the columns are subjected to particularly severe deflexions.

106. In considering lateral forces and their associated movements, Bays 3, 4, 5 and 6 of the superstructure are forced to move with the deck; Bay 1 is considered as rigidly fixed to the land. Lateral deflexion of the pier deck therefore causes Bay 2 to rotate in plan as indicated in Fig. 12(b) and (c). Fig. 12(b) shows the effect of a uniformly distributed lateral loading, whilst in 12(c) a severe vessel impact at the seaward extremity of the pier has caused the deck to pivot about a point shorewards of its centre.

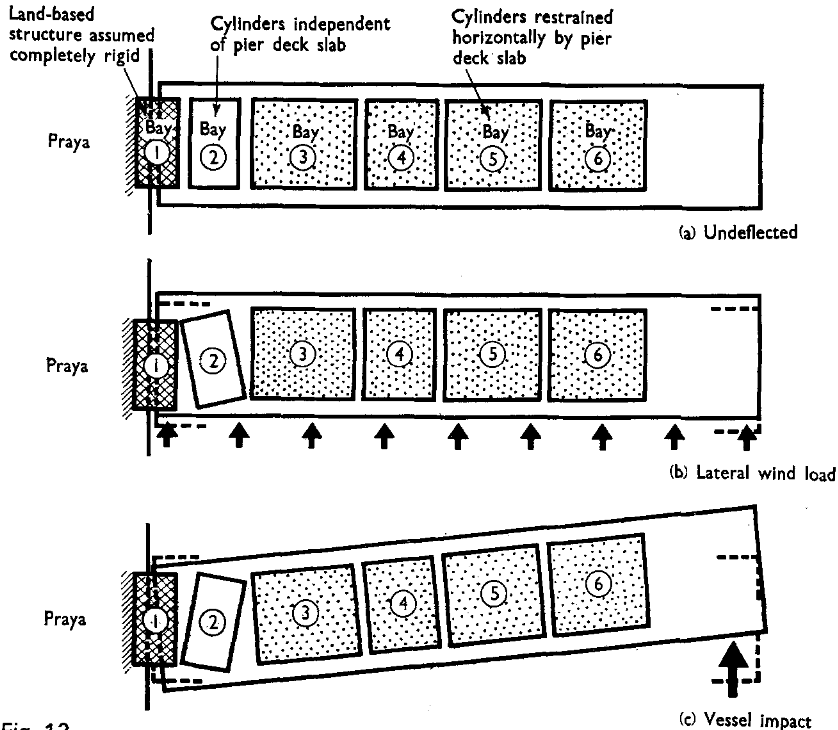

Fig. 12

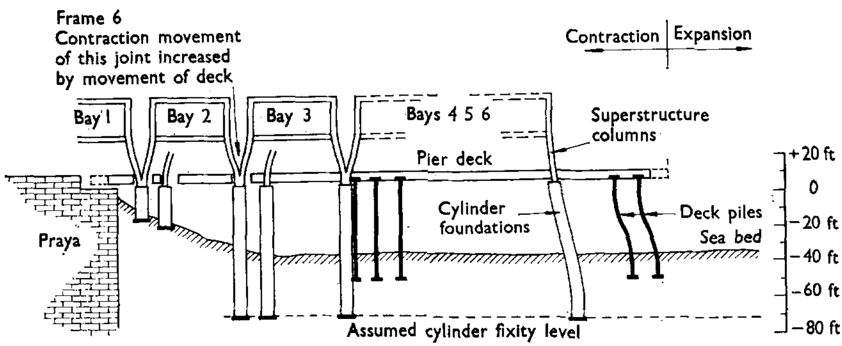

Fig. 13

107. I should like to ask the Authors if they have had any instances of severe impact by ships on the pier, and if so whether there has been any sign of excessive movement at the expansion joint between the deck and the Praya. Furthermore, has there been any noticeable cracking at the bases of the twin columns forming the superstructure expansion joints? Finally, as the pier deck is unusually thin, has there been any serious damage to it due to dropped loads or other forms of heavy impact?

Mr C. H. Garthwaite, Phillips Consultants Ltd

My firm was entrusted with the design of the superstructure. At the early design stage there were two considerations which loomed very largely. One was the fact that the ocean terminal is about a quarter of a mile long and four storeys high, and plainly there was going to be a lot of structure between one end and the other. The other was that a very heavy horizontal load had to be withstood since Hong Kong is in a typhoon area where gusting in excess of 170 mile/h can be experienced. What was needed, therefore, seemed to be a contradiction in terms, namely a structure composed of precast units which could still have the monolithic quality of concrete cast in place so that these lateral forces could be resisted.

109. The solution actually adopted was that the superstructure was precast as much as possible so that full advantage could be taken of repetition, with the exception, however, that the columns, and the haunches between the beams and columns, were poured in situ. In this way rigid multi-bay portal frames were constructed which could resist all the typhoon loads.

110. The actual details were as follows. The beams were precast full-length so that they carried themselves between columns with the minimum of propping. The ends of these beams, however, were reduced to slender tongues which enabled the in situ haunches to be formed around them at each junction. Similarly the floor slab was precast in 25 ft lengths, this being the distance between frames. Each floor unit is of ribbed form, complete with topping, and this topping was inverted at the ends so that an in situ flange could be formed over the beams without the use of any shuttering. The flange and the haunch were then poured in one operation, thus uniting the separate elements into one unit of massive strength.

111. In these and other ways the most economical and practical solution was sought. One method was in the choice of steel reinforcement. The Japanese produce an intermediate grade of high tensile steel which has a working stress of 24 000 lb/sq. in. With a wind overload of 25%, this stress can go up to 30 000 lb/sq. in. and, since this was the maximum stress permitted by the specification, this steel was ideal for the job.

112. It appears that in Japan steel is manufactured not only to their own standards but also to the American and German standards. Normal high tensile steel known in Britain would have had some unused capacity and would not have been quite so economical.

113. The two upper levels of the car park were united with precast fins which were also prestressed. The advantage of prestressing is that they could be very slender in section, and during handling no tension developed anywhere in the section. Another small point regarding these fins was that with the typhoon loading experienced at Hong Kong, the fins could have vibrated under wind load and perhaps reached their natural frequency. In order to damp this, the hand rail which is inside the building is connected to every fin, rather than to every third or fourth.

114. The steel columns over which it was intended to put a hotel, carried about 1000 tons each. Because vehicular access to the terminal is through this part of the approach structure, the size of the columns was limited by considerations of clearance on either side, and in order to carry this load of 1000 tons a column that was truly composite in design was used. Plates were welded to the largest rolled steel section available and this was cast in concrete with reinforcing bars all around plus helical reinforcement around the bars to produce the maximum carrying capacity.

Mr P. A. Cox, Rendel, Palmer & Tritton

In most modern port layouts one has to provide much larger space for storage of cargo being landed and awaiting shipment, and I was surprised to see the relatively small amount of space made available in the building for the storage of cargo. Probably the space is limited in Hong Kong and this made it desirable to put the shopping precinct in an area that the tourists could readily get at, but I would have thought that this space might have been better utilized for storing cargo. Could the Authors say what has been the experience of operation? Has this area been sufficient?

116. My second point deals with the contractual arrangements for the job. These appear to have been somewhat unusual in that although there was a consultant appointed, the design was done by the Contractor, and the Paper states in § 23 that the general conditions of contract were the ICE General Conditions for Overseas Works. I think these normally do not provide for the contractor to do the design, and I should like to know what the general amendments were to the conditions of contract to put the responsibility for design matters where it truly belonged. In this connexion, did the Contractor have to carry the cost of the additional work required on the cylinders when it was found necessary to modify the foundation conditions? The situation would appear to be further complicated by the fact that there were three or four consultants involved with the various aspects of the work, and I should like to know the division of responsibility between them and the designer and contractor.

117. Precast concrete is used quite extensively in marine works but from tenders received during recent years it does not necessarily provide the cheapest solution. In one case recently we invited tenders for a marginal wharf on two alternative designs, one on precast concrete and one based on in situ concrete, and the in situ concrete design was cheaper. Agreed that was a special case. It was a marginal wharf and access was fairly easy. But even on offshore jetties I have found that where one has two areas of fairly similar work, the one done in precast will be more expensive than the one done in in situ concrete. For a long jetty approach in Australia where we have designed the structure in precast, the Contractor elected to cast some very heavy cross-heads to each of the pile bents; he cast these in situ and in fact made sufficient supports for about one-third of the total number of beams involved in the approach. This appeared to us to be a very heavy investment in temporary works, but he assured us that this was cheaper.

118. Even if precast concrete is more expensive, it may still offer some advantage to the client, in that the work should be done more quickly, but again this is not always borne out by information shown in tenders, and I wonder whether the client really gets the benefit that he should get from precast concrete when used as extensively as it has been in this job.

Mr W. R. Thorpe, Sir William Halcrow & Partners

My first question is really a supplement to one asked by Mr Cox concerning the contractual arrangements described in § 23, which are of very great interest. I should like to know how the prime cost was computed, first at the tender stage, and second at the 'as constructed' stage, so as to establish whether or not there is any saving payable to the Client.

120. I should also like to know whether during the course of construction both the prime cost and the on cost elements were paid out in equal proportion in interim valuations.

121. I would be interested to know whether the Authors genuinely feel that this contractual arrangement really showed a benefit to the Client, compared with the more conventional arrangement of measured work. In § 26 it is stated that the Main Contractor undertook the role of Managing Contractor. This I take to mean that he took on responsibilities of co-ordination on a master network and that he did not in fact enter into formal sub-contract agreements on the Federation pattern. If my supposition is correct, I wonder whether this co-ordination job is not one which could equally well be undertaken by the Consulting Engineers who presumably were well represented on the site and were well fitted to do this. Many engineers are concerned with jobs which involve many disciplines and varieties of sub-contracts and

specialist work, and this co-ordination function is very important. I have read recently in *The Financial Times* an article stating that Urwick Orr, a firm of management consultants, were retained simply to do a co-ordination job during the development of a new factory for the Royal Worcester Porcelain Co., and, as one who works for a firm of consulting engineers, I feel that this is a job which should be kept within the family, as it were.

122. I have one or two technical points concerning the substructure. I notice that the Authors refer throughout to the use of blast furnace cement. I wonder why this was done rather than relying on the usual very high strength concrete. It is quite clear that there was very high strength concrete and according to the figures which are quoted for the cylinders they attained a strength of 8000 lb/sq. in., presumably at 28 days.

123. In this connexion, I see that the water–cement ratio ranged from 0·43 to 0·29. It seems to me that in dealing with water–cement ratios of that kind re-design of the mix is required. I should like more information on that point.

124. Could the Authors say how they managed to inspect the inside of a 28 in. dia. pile? I should think that some form of television camera would be needed.

125. High working loads of 600 tons have been mentioned for the cylinders. Could the Authors give more details of the cylinder foundations? Were they treated primarily as end bearing or was a combination of end bearing and skin friction used? What factor of safety was expected? How was it possible to correlate the load bearing capacity of the material on which the cylinders were founded with the standard penetration and other tests?

126. In the Paper it is mentioned that the reinforcing bars were grouted up by pouring. I could not see that any measures had been taken to prevent the very workable mortar used in jointing the cylinders from getting into the ducts of the bars. I wonder whether the Authors are quite confident that they successfully grouted off all the ducts.

127. My last point is this. Fig. 4 shows what appear to be 20 ft ISO containers. This must be one of the most unconventional container terminals in the world. Do they in fact manage to handle containers there?

Mr J. T. Edwards, Freeman Fox & Partners

I, too, should like a further amplification of the contractual position. The maximum prime cost clearly had to be fixed when a large amount of the design had not even been started and there were very significant additions such as, I understand, the complete top car deck. I wonder how the increase in this prime cost sum was determined from time to time as these changes took place.

129. The second point concerns the actual channel of communication between the Architect and the Contractor for working drawings. This is always a difficult problem and there must have been cases here where the Architect issued a working drawing which the Contractor would consider justified an increase in the prime cost. I should like to know how that situation was dealt with and whether all the Architect's drawings went through the main Consultant before going to the Contractor.

Mr R. Leyland, Building Design Partnership

I understood Mr Cochrane to say that the cylinders at the end of the jetty were more or less on the limit of allowable stress, and Fig. 11 showed a movement of $\frac{1}{2}$ in., whereas I understood the Authors to indicate that the long term movement at the end of the jetty was of the order of 1 in. This would indicate that the cylinders at the end of the jetty would be grossly overstressed.

Hong Kong meeting

This Paper was also presented by Mr J. C. Faber at a joint meeting of the Engineering Society of Hong Kong and the Hong Kong Joint Group of the Institution of Civil

Engineers on 10 February, 1971. The questions asked are summarized in the following paragraphs.

132. What were the problems with the gangways and were they successfully overcome? Were the steel piles of the old wharf pulled out or cut off? How was the hard dredging carried out?

133. For what conditions were the piles designed? How were the pile lengths established and was it necessary to lengthen any of the piles?

134. What values of the standard penetration tests were taken in determining the depth of the cylinders? What was the maximum settlement and was it due to disturbance of the soil during sinking the caissons? Did the presence of boulders cause complications in constructing the cylinders? For what length of time was the preloading of cylinders applied?

135. Was any provision made for horizontal movement of the superstructure columns relative to the deck? Was differential settlement taken into account in the design of the superstructure? Why were props under precast beams necessary during construction? Was prestressed concrete considered in the design of the superstructure?

Messrs Faber, Faber & Thomas

The Authors agree with **Mr Pope** that they have been too concise. They had considerable difficulty in keeping the Paper within the limited space allotted to them. They are grateful to **Mr Cochrane** and **Mr Garthwaite** for enlarging on some aspects which were mentioned too briefly in the Paper.

137. In reply to the questions on piling and dredging, the steel piles of the old wharf were extracted and were generally found to be in good condition except for the top section where severe corrosion had occurred in and above the tidal range.

138. The rock which had to be dredged was loosened by explosives and removed by a grab dredger. It was found that some of the weathered rock could be shattered by beehive charges placed on the sea bed but much of the rock required blasting. Drilling and setting the charges was carried out in a diving bell.

139. Mr Cochrane has very ably described the end conditions for which the piles were designed. There are no raking piles; all horizontal forces from berthing impacts and from wind and tide on ships alongside are resisted by the vertical piles in bending. The width and stiffness of the deck in the horizontal plane distributes these loads over a large number of piles. In reply to **Mr Leyland**, the observed total movement of about 1 in. agrees with the anticipated thermal movement of $\pm\frac{1}{2}$ in. given by Mr Cochrane.

140. The piles were driven to a set determined from loading tests on the test piles. Subsequent tests on working piles allowed a revision in the required set and some saving in the length of piles. This was due mainly to the greater efficiency of the hammer used in the work which had not arrived on site at the time of the initial tests. The policy was to select piles rather longer than necessary on the basis of the approximate soil profiles and on the experience of driving previous rows. No piles had to be lengthened; it is, of course, much quicker to cut piles and time was short. **Mr Thorpe** asked about the inspection of the insides of the piles. This was done by a slim engineer. It was very necessary as the mandrel method was very new and it was essential to ensure that there were no cavities or anything going wrong, and the inspection was very thorough.

141. Mr Pope's comments on the merits of the separate foundations for the building are pertinent. It was stated in § 20 that design loads had been estimated. There were, however, two areas, at the concourse and at the plant room, where not only the loads but also the location were uncertain until a comparatively late stage in the design. The separate foundation also allowed the extra car-parking floor to be added after the construction of the deck had started.

142. Fewer piles allowed faster progress with the deck to increase the working area which was an important consideration when the 'site' at the beginning of construction was a strip of praya about 40 ft wide and about 400 ft long.

143. In similar circumstances, the Authors would use the same method again, but with some alterations to the technique in sinking the cylinders.

144. The cylinders were primarily end bearing with only a proportion of the load carried in friction. The values of the standard penetration test used in determining the length of the cylinders were based on the laboratory tests of samples taken in the site investigation and checked against the end bearing values obtained in the pile tests. A factor of safety of three was expected.

145. Minimum values of N between 30 and 51, depending on the design loads, were required together with a minimum penetration into the firm stratum. The measured values of N ranged from 38 to 160. No relationship could be found between measured N values and settlement. The maximum settlement was of the order of $4\frac{1}{4}$ in. but the maximum differential between two adjacent columns in a frame was about $1\frac{5}{8}$ in. In the Authors' opinion, the larger settlements were due to disturbance of the soil during sinking and excavating the caissons.

146. The preloading mentioned in § 52 would to a great extent restore the soil beneath the cylinders to its original condition and the settlements in this part of the building were not excessive. The preloading was applied for periods varying from 12 hours to $7\frac{1}{2}$ days depending on the amount of settlement and on the time/settlement curve.

147. No special provision was made for differential settlement in the design of the building. The tolerable differential varies from about $\frac{3}{4}$ in. in the short spans at the sides to $1\frac{1}{4}$ in. in the long central span. Provision for horizontal movement of the columns relative to the deck was made near the shore end where the piles and cylinders were short, by forming oversized holes in the deck and sealing round the columns with a compressible filler.

148. Some problems were experienced with the expansion joints particularly in the landward half of the building in the area of greatest settlement. The upper roof is exposed to the sun, the lower car park although open at the sides is shaded, the two floors below this are air-conditioned, and the marine deck is shaded inside the transit shed but exposed to the sun at the sides. There is, therefore, least thermal movement at the second floor and greatest at the roof. The sealing detail at the roof was redesigned and a thicker filler was provided in the gaps between the double frames within the building. There are some hair cracks in some of the double columns and in the edge columns supporting the roof but no serious cracking has been found.

149. The most severe impact occurred when a ship rammed the pier as a result of engine trouble after leaving one of the adjacent piers. The fenders were broken and a small notch was cut in the edge of the deck; the shock of the impact was felt all over the building, but no other damage was found. In $4\frac{1}{2}$ years there have been six heavy impacts on the outer corners in which the ship has been damaged after exceeding the full 280 ft tons energy absorption of the wheel fenders. Full particulars of all berthings are not available but it is estimated that the occurrence of damage is about $\frac{2}{3}$% of the number of ships which approach with risk of hitting the corners.

150. There were three main reasons why the upper floors were not used for storing cargo as was suggested by **Mr Cox**. The first floor is the level on which the passengers land and large areas are needed to absorb the complement of two large cruise liners; the revenue from the shops is much greater than the revenue from the cargo storage; the clients have eight multi-storey warehouses adjacent to the Terminal. Ships passing through Hong Kong only discharge or load a part of their cargo and it is common to see them working simultaneously onto the wharf on one side and into lighters on the other. With the very few customs restrictions and the short distances to the industrial areas, cargoes can be dispersed and assembled very quickly and do not stay

long in the transit shed. In reply to Mr Cochrane, there has been some slight chipping and scoring of the granolithic finish but no structural damage has yet occurred.

151. **Dr Jellett** asked about customs. There are practically no formalities as Hong Kong is virtually a free port and the list of dutiable articles is short. Moreover, the majority of passengers, certainly in the larger ships, are tourists in transit. Facilities are provided in the transit shed for the inspection of cargo.

152. He also asked, as did Mr Pope, about the gangways. They were constructed with a steel framework clad with aluminium. The Authors, too, took many measurements of ships' doors and coamings and also decided on a single point landing hook with interchangeable jaws of different widths.

153. The gangways were required to be connected to the ship and left virtually unattended for two or three days at a time. This requirement together with the comprehensive warning and safety devices gave rise to a number of problems in the hydraulic and electrical circuits. It was also found that the resistance to telescoping in the 'freewheeling' condition was unsatisfactorily high until the original roller guides were replaced by PTFE slides. These difficulties were in the nature of development work on a new design and for various reasons much of this work was done on site instead of at the manufacturers' works before delivery. The gangways have been working satisfactorily now for over four years.

154. Messrs Cox, Thorpe and **Edwards** asked for more information on the contractual arrangements. The original contract was for the pier and the structural shell of the building only. The appointment of the Contractor as Managing Contractor for the finishes and services was in effect an extension of the first contract under somewhat different terms so that these works could be carried out as nominated sub-contracts with a recognized chain of authority. The Authors agree with Mr Thorpe on keeping things in the family provided that the dangers of nepotism can be avoided.

155. It is not unusual for contractors who are tendering for large works on designs prepared by consulting engineers to offer alternative proposals to their own design. These alternatives are sometimes accepted and the situation is then much the same as asking the contractor from the start to put forward his preferred method of construction for which he must carry out the structural design in order to prepare his tender. The general planning of the building and detailed specification of loadings, permissible stresses and design criteria were prepared by the consulting engineers who, during this process, made studies of a number of different methods of construction from reinforced and pre-stressed concrete to composite construction. The Contractors' structural calculations and drawings were checked and approved in the Consulting Engineer's office before being submitted for the approval of the local authorities or before being issued to the site. The final responsibility for design therefore rests with the Consulting Engineers.

156. The introduction of a guaranteed maximum prime cost was made at the request of the Clients. This is not unknown in England in the form of a 'target cost' contract. It introduces an extra incentive to keep the cost as low as possible, since any saving would be shared by Client and Contractor.

157. The general conditions of contract were modified by detailed special conditions which defined the guaranteed maximum prime cost and the fixed fee, provided for the amendment of these sums in the event of variations, specified the method of payment of prime cost and fixed fee, required the Contractor to keep full accounts of all items of prime cost and provided for the inspection and checking of these accounts and the supporting vouchers. Monthly payments were made for prime cost and on costs in the ratio of their tender amounts.

158. The original prime cost and the fixed fee were quoted as separate items which together made up the total amount of the tender. Some difficulties in interpretation did arise in determining what was a variation justifying an increase in prime cost, but these were few compared with the number of variations. The values of the variations

were negotiated. It must not be forgotten that this was a competitive design and construction contract and a very full design and a bill of quantity were prepared to enable the Contractor to establish his tender, and these formed the basis for negotiating the cost of variations.

159. The contract provided that any saving on the guaranteed maximum prime cost would be shared equally between the Contractor and the Client. The effect of any extra costs such as the additional work on the cylinders would therefore be shared equally between the Contractor and the Client until the prime cost reached the maximum, any excess being then borne entirely by the Contractor.

160. The foregoing procedure applied to the civil and structural works only. The nominated sub-contracts were let as measurement contracts on priced bills of provisional quantities which formed part of the tenders.

161. It is possible but by no means certain, that the cost of the work might have been a little lower with the normal form of contract. The time required for completion would have been appreciably longer. The benefit lies in the value of time which is difficult to quantify.

162. Mr Edwards asked about the channel of communication, which is best explained by Fig. 14.

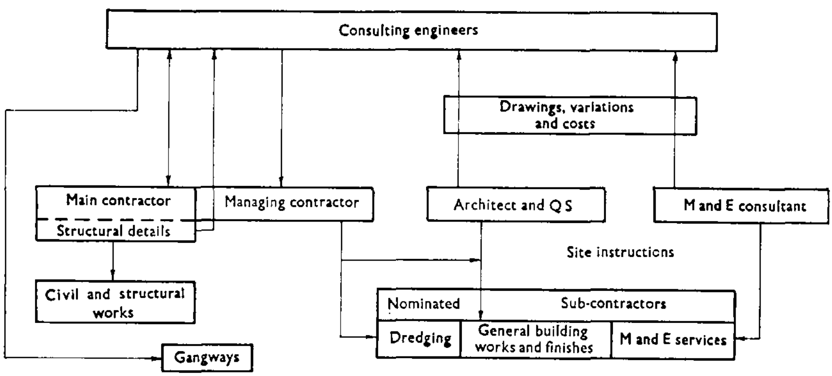

Fig. 14. Channels of communication

163. Mr Cox commented on the relative costs of precast and in situ work. The Authors agree that precast concrete is not necessarily cheaper in actual cost of construction, but they have no doubt that it was the best solution for the pier. To maintain the same progress with in situ work, a large quantity of shuttering and temporary supports over water would have been required with a serious risk of delays due to damage by typhoons. The limited working area on the praya mentioned in § 142 was also an important factor.

164. Having set up a precasting yard for the piles and main deck, it seemed reasonable also to adopt precast construction for as much as possible of the superstructure. Erection of the building was quicker; on the occasions when progress fell behind schedule, it was in situ work causing the delay. In other circumstances in situ work would probably have been chosen, particularly in Hong Kong.

165. Mr Thorpe queried the use of blast furnace cement. It has a rather better resistance to chemical attack than ordinary Portland cement.[1] Older piers in Hong Kong constructed with sulphate resisting cement and Portland pozzolana cement have required less maintenance than piers constructed with ordinary Portland cement.

The Authors agree that the most important factor in resistance to seawater is the impermeability of the concrete.

166. The grouting of the bars in each length of cylinder was completed before the next length was threaded over the projecting bars, and before the mortar was placed. The Authors can assure Mr Thorpe that all the ducts were grouted.

167. The ISO containers shown in Fig. 4 were carried on the upper deck of conventional cargo ships. Where their contents were heavier than the ships' gear could handle, it was necessary to unpack or pack them on deck. The 250 ft square area at the end of the pier has, however, since been used for handling on chassis 35 ft Sealand containers landed from self-sustaining ships. About 80 containers could be accommodated in this area with another 24 at a freight station nearby and the maximum number of containers put on one ship was 130. Now that a container yard has been developed at the far end of the clients' property, the Ocean Terminal is no longer used for handling containers.

Reference

1. NEVILLE A. M. *Properties of concrete.* Pitman, London, p. 341.

Corrigendum

In §74, for *the overturning of the extended moment gangways* read *the overturning moment of the extended gangways.*