Rainfall

88. Mean monthly rainfall in inches:—

Month	*Maximum*	*Minimum*	*Average*
January	8·40	0	1·26
February	7·95	0	1·75
March	11·45	0·16	2·85
April	17·30	1·21	5·36
May	48·90	1·15	11·25
June	34·40	2·34	15·30
July	30·00	4·57	15·20
August	34·30	1·74	14·30
September	30·60	0·64	10·40
October	24·00	0·18	4·33
November	8·81	Trace	1·68
December	4·90	0	1·03
Year	120·0	45·8	84·8

Discussion

The Chairman, after proposing a vote of thanks to the Authors, said he was extremely interested in the scheme because he had been the first engineer to carry out the investigation of the existing Kai Tak airport and to prepare plans for its development for use by civil and military aircraft, nearly 30 years ago. At that time the width of the existing airfield had been 600 yd. His proposals had involved a small extension, to 800 yd, and some of the authorities in Britain had thought that he was being extravagant.

90. There was one point about the existing airport of which the Authors might not be aware. The site had not been developed in the first instance as an airport but as a housing site. A sea-wall had been built across the chord of Kowloon Bay and the area had been filled by dredging shelly sand from the Lei Mun Pass, covered with disintegrated granite brought from the hills to the north-east. In using dredged sand and disintegrated granite the present engineers were employing the same materials for fill as had been used in the original development of the Kai Tak area.

91. The Authors referred to two factors which had caused them to proceed with the present scheme. To his mind those, though important, might not be the most important; the most important factor, as anyone who had been in Hong Kong would agree, was to get away from the hills. Those hills were a terrible menace to flying, and by moving the runway away from the hills to the north and more into the harbour that objective had been achieved. That objective had been in mind, he thought, in proposing the other schemes—the Ping Shan, the Deep Bay, and the Stonecutter scheme, which all allowed a runway usable from both ends. It was very unpleasant to have to land on a runway which was at a dead end, with the knowledge that in the event of an overshoot there was nothing which could be done to avoid running into the hills. The Authors' scheme was bold and imaginative and got away from the troubles of the existing airport.

92. It was curious that Kai Tak had now gone full circle. It had started as a housing site but had never been developed as such, and now, after 30 years, part of it was in fact to be used for housing purposes!

93. From personal knowledge he wondered if the Authors' borings had gone far enough. Fig. 7 showed the existing 07/25 runway with the positions of the borings marked, but those borings did not go into the original developed area. That area was not composed, he thought, of the materials shown in Table 1, but would be found to consist of the shelly sand to which he had referred and the overlay of disintegrated granite.

Professor A. W. Skempton (Professor of Civil Engineering, Imperial College, University of London) congratulated the Authors on the Paper and on the site investigation which they had made at Hong Kong. It was extremely refreshing to see the realistic way in which that investigation had been carried out. An investigation of such magnitude was in itself something of an achievement, but its true value depended upon the interpretation of its results by the engineers. In the present case the Authors had shown

admirable judgement in not accepting the shear strengths, as first measured, of the clay underlying the proposed sea-walls. Vane tests had therefore been made and tended to confirm that the strengths as measured from the samples had been too low. As a check the Authors had then analysed a recently completed sea-wall at Kowloon Bay, where conditions had been similar to those at their proposed sea-walls, and that analysis had confirmed the vane-test results. As he understood it, the final design of the sea-walls had then been produced, with a factor of safety of 1·55 on the vane-test results. It was evident that that decision must have saved a great sum of money, as well as time, and Mr Grace had mentioned in presenting the Paper that the sum of money involved was in fact about £800,000.

95. That was the most severe case which Professor Skempton had so far come across, but not the first, where the samples had been far from satisfactory. It had begun to be clear just after the war that troubles of that sort could arise, and almost simultaneously in Sweden and in England the vane test had been developed precisely to cope with the problem. On the whole, it seemed to be very satisfactory.

96. More recently attention had been paid, particularly in Scandinavia, to improvements of the piston sampler. He noticed in the Paper that a piston sampler had been used, but he imagined not in the clay which had given trouble. Perhaps the Authors would state whether the piston sampler had been used in that clay. If it had been, a difficult situation would have to be faced, because general experience up to the present was that the piston sampler gave reliable results even in quite sensitive clays.[5]

97. Could the Authors give more details concerning the clay, such as the water content, liquid and plastic limits, and the variation of strength with depth? In normally consolidated clays the strength c at any depth was proportional to the effective overburden pressure p, and the ratio c/p had been shown to be correlated with the plasticity index of the clay* (Fig. 21). Therefore a useful method existed for checking the strength obtained

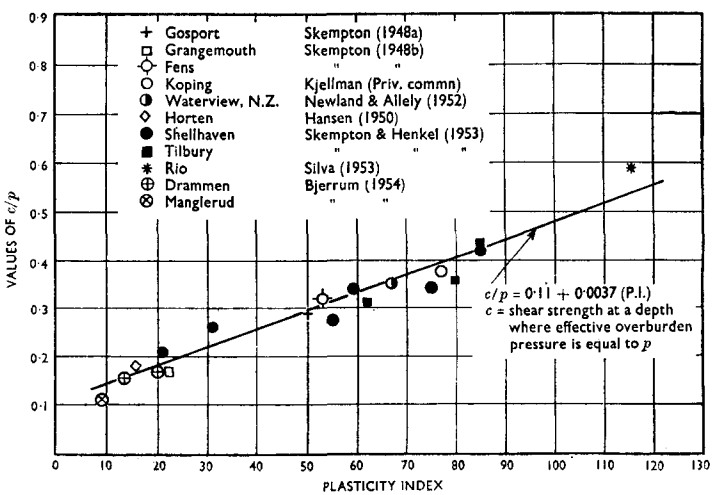

FIG. 21

* That correlation, and full references to the sources of information, were given by Skempton in discussion on "The structure of inorganic soil." Proc. Am. Soc. C.E., vol. 80, Separate No. 478 (1954), p. 19. Additional data from Bjerrum (*loc. cit.*) had been included in Fig. 21.

[5] Further references are on p. 325.

in normally consolidated clays, although, of course, nothing could be better than a full-scale check on the stability of an existing structure such as the Authors had made on the Kowloon sea-wall.

98. It was difficult to say which was the more unsatisfactory, to forego a proper site investigation or to trust blindly in the results obtained. Those who had been concerned with soil mechanics from the early days had always emphasized that it could only supplement the judgement of the engineer. It could rarely be a substitute for such judgement. In their wise treatment of the problems at Hong Kong the Authors reminded Professor Skempton of a remark which his friend Dr Hamilton had made in print some years ago,[6] when writing of the great eighteenth-century French engineer Perronet, whose work, Dr Hamilton said, was "backed by a capacity for applying theory when he found it helpful, without being intimidated by it when it conflicted with his judgement."

Mr R. F. Lloyd-Jones (Partner, Norman and Dawbarn, Architects and Consulting Engineers) said that the unusual difficulties encountered in trying to site the airport at Hong Kong were obvious. Probably no airport was ever built where the ideal solution could be applied without some compromise with practical issues, but there could rarely have been a more awkward site. After seeing the film it was possible to understand some of the difficulties of developing the alternative sites, but could the Authors give any sort of comparison in the usability figures between their estimate for the Kai Tak airport when it had been developed and what they might have been if one of the other sites, such as Deep Bay or Stonecutter's island, had been developed? He appreciated that the decision to use Kai Tak had already been taken when the Authors' firm had been appointed as consultants and consequently those figures might not be available.

100. Those problems, which arose at an early stage in the development of an airport, were difficult to evaluate. A balance had to be found between political problems, cost, amenities, and flying requirements, and it was always valuable to know on what basis decisions had been made elsewhere.

101. He had asked about usability because he understood that the nearest diversionary airfield was about 700 miles away, so that usability seemed to be more important at Hong Kong than at most places.

102. Another point about the alternative sites was their remoteness; but the time that it took to get from the town centre to the airport should be related to the average length of passenger journeys. Did most of the passengers from Hong Kong make long-distance flights or journeys of only a few hours?

103. With regard to the layout finally adopted, one approach was based on instrument conditions and the other, the curved approach, on visual conditions. Was that of particular significance? Was it intended that at some time there should be some form of radio guide or assistance on the south-east approach? Conditions limiting the use of the airport might be those permitting safe use of the north-west approach regardless of the direction of landing, since account would have to be taken of the possibility of an aircraft, approaching from the south-east, overshooting and flying over the area to the north-west.

104. For the runway a width of 200 ft had been adopted, and he thought he was right in saying that at certain other airports with almost identical conditions a width of 150 ft had been thought sufficient, even for the latest American jet aircraft.

105. In § 22 reference was made to the extension of the runway by 1,140 ft at its landward end, to a point 60 ft short of the first elevated lamp in the approach lighting. The Authors went on to say that that extension could be used for all operations except landing from the north-west. He did not think that the full 8,340 ft could be regarded as available for take-off towards the north-west; it would be assumed that the aircraft would start its climb in sufficient time to keep above the 1-in-40 approach plane. In other words the available length would be 7,200 ft plus a further 260 ft, making 7,460 ft.

106. He would be interested to know more about the design loading for the pavement, which seemed to be a little high for the class of airport. Had a comparison been made with the loadings adopted at other airports of a similar kind? It was a question which always arose in the design of an airport. There seemed no very definite standard loading

which could be taken, and it was left very largely to the discretion of the engineers to decide what should be adopted in each case. Since it could be expensive, it would be valuable if at some time a more uniform basis for design could be agreed.

107. Finally, he would like to know whether it was intended to construct the apron and taxiways to have a greater strength than the runway, and if so by how much; and whether there was going to be any variation in the design strength of the runway itself as between its ends, the middle, and the edges. He hoped that information would later be given about the lighting and radio, since it would be interesting to see what modifications to the normal arrangements would be made to deal with the curved approach.

Dr H. Q. Golder (Director, Soil Mechanics Ltd) said that after reading the Paper he had intended to begin his remarks by saying "God forbid that I should ever have to land on this airport when there is a south-east wind blowing!" Having seen the film, he felt that it would terrify him even more to come in over the hills and then over the town down to an airport which could not be seen, and then make a steep right-hand turn. He had put that to one or two airline pilots, and he found that they did not like it much either. It seemed surprising that the scheme had been accepted. He knew that it was not the Authors' fault, but it was astonishing that such a scheme should be acceptable at the present time. Dr Golder took it that the new airport was not entirely a daylight airport, but he was not clear about that from the Paper.

109. In § 47 the Authors mentioned that undisturbed samples had been taken of sand. That sand was the sand which was going to be used for fill. There might be a good reason for it, but it seemed odd to take undisturbed samples of a sand which was going to be used in a disturbed condition, and perhaps the Authors could give the reason. Possibly it had been because they had to fill the hole with silt, and wanted to avoid mixing sand and silt, but it must have been a fairly expensive operation.

110. The main point which he wanted to discuss was the one which Professor Skempton had already dealt with and which Dr Golder found disturbing, namely, the difference between the vane tests and the compression tests. It was a serious difference, and it was completely unexplained. The Authors might have further data, and Professor Skempton had already asked for further information, but it seemed to Dr Golder that in dealing with a clay with a sensitivity of between 2 and 4—he believed that the average was $2\frac{1}{2}$—and with shear strengths of between 400 and 1,500 lb/sq. ft, with careful sampling there should not be the differences which the Authors had found; the vane strength should not be 60–70% higher than that shown by the undrained triaxial tests.

111. The tests done in the site laboratory and shown in Fig. 11b did not answer the problem. Those results were what would be expected. Had they not been, there would have been a further question to be answered. £70,000 having been spent on site investigation some further effort should have been made to resolve the anomaly. The obvious explanation was that the sampling had not been carefully done, but the Authors and the contractor who had done the work were known to be experienced in that type of work, and he felt that there must be some other explanation.

112. To refer to the use of a piston sampler was not enough; he would like to know what type of piston sampler had been used, because it was possible to design and make a bad piston sampler as well as a good one, and a piston sampler could have a high area ratio, just as the ordinary 4-in. sampler normally used could have. More information was desirable about that. He had intended to ask what sort of vane had been used, but that question had been answered by the film, which showed that the vane had been put down inside the borehole. That should make it possible to determine after the vane test, as the boring proceeded further downwards, the material which had been tested by the vane, and cut out the possibility that lenses of silt or sand had been responsible for the higher strength values measured by the vane.

113. He hoped that the Authors in their reply would be able to give a little more information about what they thought were the reasons for the anomaly, which, until it had been explained, must be disturbing to anyone who had much to do with site investigation.

Dr R. S. Millard (Road Research Laboratory) remarked that on the first part of the Paper, which was concerned with the siting and layout of the new runway, he had little to record but his admiration for the bold and imaginative decision to project it out to sea. That boldness was again in evidence in the decision to remove two hills and use the spoil for filling on the airstrip. That was not in itself remarkable, but one of the most densely populated areas in Kowloon lay between the hills and the airstrip, and it was no mean achievement to conceive and put through a plan which appropriated a main street through the middle of Kowloon entirely for the use of contractors' lorries and erected barricades on each side of the street. The Chinese appeared to bear that with stoicism, and even with indifference, because commercial life seemed to go on normally on the pavements on the other sides of the barricades, but it was difficult to imagine that the proposal had been put through easily and it would be interesting to learn whether the disturbance of the life of the city had been borne with equanimity.

115. The engineering "meat" of the Paper came in the second half. After reading that he had felt that there were several points which it would be useful to amplify. The further Paper which had been promised might well provide some opportunity for that, but the point which he wanted to make concerned one raised by Professor Skempton, who referred to the exercise of engineering judgement in applying theory and in using the results of site investigations.

116. Dr Millard felt that one of the chief purposes of Papers presented to the Institution was to take younger engineers step by step through the stages leading to such decisions and to give them experience by proxy. There were two or three points in the Paper to which he would like to refer and with regard to which he would like to ask the Authors to go through the steps which had led to their decisions.

117. The first was in § 63 and concerned the estimation of settlement in the deposits under the silt. That estimate had been made with some precision, although it was stated that the variable nature of the material made straightforward estimation from consolidation tests impossible. There seemed to have been some engineering cunning, and it would be instructive to learn more about it.

118. In § 71 an upper limit was given for the fines content of the sand fill which was being imported, and that limit had been imposed to ensure rapid consolidation. A limit of 25% of fines, 25% passing 200 mesh, seemed a little high, and he believed that an attempt was being made to work to a lower limit of 15% for the upper layers of the filling. Could the Authors indicate on what basis that selection had been made? At the same time, with the Chairman's permission, he would like to give notice of another question, to be asked when the second Paper which had been promised was presented. What means were going to be adopted to ensure that the sand dredged from the channel was kept within those grading limits. It seemed to him that that was going to be a very difficult problem.

119. The very low densities found in the decomposed rock filling in the foundations on the terminal area suggested attempts at sabotage while the Japanese construction had been in progress. They were remarkably low, and the low C.B.R. figures found were certainly understandable. On the data given, however, he had some difficulty in following the suggestion that a sand sub-base might be required where the decomposed granite was already in place. The density/moisture content/C.B.R. data given in Fig. 15 showed the value of heavy compaction in giving high bearing capacities. To him, the problem seemed to be more one of the weather at the time that the work was going to be done rather than of the ultimate moisture conditions which would be found in the decomposed rock. If the work was done in the winter, when the weather was dry, there was every chance that the decomposed granite could be disturbed and allowed to dry out to a moisture content at which it could be compacted satisfactorily; if that were done he thought that any subsequent wetting-up would not produce great reductions in bearing capacity. On the other hand, if the work had to be done in the summer, with high rainfall, and it proved impossible to reduce the moisture content of the soil, there seemed to be no alternative but to remove the material and replace it either with sand or with newly-won decomposed granite which should not be wet and which could be compacted in thin layers.

120. In § 76 there was a passing reference to soil cement as a possible base material. It would be interesting to learn the basis of the mix design on which the comparison with crushed stone had been made. In saying that he was not attempting to question the decision which had been made; crushed stone was available in large quantities in Hong Kong. He would like the Authors, however, to give more factual information on the comparison.

121. Lack of space had prevented the Authors from describing their plans for surface-water drainage on the runway. The cross-section in Fig. 13 suggested a cambered profile with surface water draining over the ground and through the side walls. There was a strip 20 ft wide at the edge of the runway of turfed sand through which it seemed likely that some surface water was going to percolate. The relatively free-draining sand was surrounded below and probably at the sides with soils of low permeability, and the sand fill seemed to be something in the nature of a reservoir in which water could collect. Was not there a likelihood that the water would rise during times of heavy rainfall in the sand to a dangerously high level?

122. In their Conclusion the Authors referred to the magnitude of the site investigations which had been made before the work had been begun. Engineers in Public Works Departments abroad would look at that with envy, but there could be no doubt that the cost of employing the team of engineers and their assistants would be saved many times by the more economical design. The project described by the Authors was, of course, spectacular and had many novel features, so that the need for a thorough site investigation could not be disputed. Almost all civil engineering works overseas, however, had some novel features not found in work in Britain, and the figure quoted, of 1% of the total cost, for the general cost of preliminary investigations, was certainly not high in relation to the money and constructional effort which they would normally save.

Mr M. J. Tomlinson (Chief Engineer, Central Laboratory, George Wimpey & Co. Ltd) said that the role of his firm in the site investigation was that of the contractor for the borings. The planning of the investigation and the way in which the result was used had been decided by the consulting engineers, and the Paper showed the very thorough way in which that had been done.

124. He would, however, like to comment on the problems of taking undisturbed samples in soft clays and silts from floating craft. When comparing the vane tests with the results of laboratory shear tests on undisturbed samples, it should not be forgotten that the work had been done from a moving platform at sea. When taking undisturbed samples particularly at shallow depths below the sea, there was difficulty in avoiding disturbance resulting from movement of the borehole casing, because until the borehole casing was embedded in the soil to sufficient depth to be self-supporting it had to be held by the ship in the slot on the boring platform. Therefore as long as the ship moved, the casing also moved, so that until the casing had sufficient embedment to hold itself upright it would move and disturb the soil beneath its cutting edge, and the "undisturbed" samples would be wholly or partially disturbed, depending on the degree of movement of the casing. Even with a piston sampler, therefore, it was not surprising that there had been quite a difference between the vane tests and the undisturbed samples in the zone from the sea-bed down to 20 to 30 ft.

125. Their chief interest in the results of the site investigation came at the tendering stage of the main contract. Like Dr Millard, they had been very seriously concerned with the problem of finding suitable sand fill for the reclamation work. Taking all the borings which had been done in the dredging area in Hung Hom Bay, nearly half the samples showed that the silt content was above the 15% specified as the maximum, and there did not seem to be any particular horizon where clean sand occurred. The silty sand was distributed quite at random. The dredging had to be undertaken to depths of about 80 ft below sea level and pumped 2 miles to the reclamation area. Therefore, there appeared to be serious difficulties in separating the clean from the dirty sand. It would be interesting to learn from the Authors how the contractors had tackled the problem.

126. There was also the question of the level of the runway surface in relation to sea

level. According to Fig. 10, there was only about 6 ft of freeboard between M.H.W. and the top of the runway margins. He did not know whether typhoons created a tidal surge in Kowloon Bay, but he believed that the wave heights in typhoon conditions were 6–8 ft in Hong Kong harbour. Of course, no aircraft would land at time of typhoons, but there might be a risk in typhoon conditions of waves washing up the sloping side of the sea-wall and over the runway margins, thus causing erosion and possible undermining of the runway edges. Did the Authors feel satisfied with the 6 ft of freeboard which they had provided?

127. In § 52 the Authors referred to the stability of slope of the sea-bed silt. They referred to the material in general terms as "silt", but that term did not quite describe what the material was like. Fig. 8a gave grading tests on that material and showed that it was a silty sand or a sandy silt rather than a straightforward silt. The Authors quoted a shear strength of 100 lb/sq. ft. He did not think that an under-water slope of 1 in 2 would be stable if it were cohesionless material with a shear strength of only 100 lb/sq. ft. There must have been an appreciable angle of internal friction to give stable slopes of 1 in 2.

128. Referring to the cost of the investigation, did the Authors think that the cost of £70,000 would have been incurred if the airport had been wholly on land? Quite a high proportion of the cost must have been due to the marine side of the investigation. It would be interesting to know what a site investigation for a major airport project on land would cost.

Mr R. Broadbent (Chairman, Jet Planning Group of the Ministry of Transport and Civil Aviation) said he was not an engineer but a pilot. He had had some small part in the initial work of the survey since he had led the Ministry's survey party in 1951 which had started all the work. He spoke that evening, however, as a private individual and not as a member of the Ministry of Transport and Civil Aviation, and his comments were limited to the first part of the Paper.

130. He thought that the site layout was important. He could not claim the Chairman's 30-year acquaintance with Hong Kong, but he agreed that the problem there was one of the worst which could confront an engineer or an aerodrome planner. His terms of reference had been to carry out an operational survey of the site. In view of the very difficult surroundings, with mountains up to 2,000 ft high within 2 miles of the aerodrome, and with the bad weather which prevailed in Hong Kong—for 25% of the time the visibility could be expected to be less than 3 miles and/or the cloud base less than 800 ft—it was quite a serious problem.

131. Only two approaches were available, through the Lei Mun Gap from the south-east and over Kowloon from the west, and there was also the fact that the significant winds blew from the east. The strong winds were easterly and south-easterly. There were a few very strong winds from the north as well, but for all practical purposes the significant winds were easterly. He had been interested to hear a previous speaker say that he would hate to land on the new runway with an easterly wind. For 73% of the time he would have to do so, so that if he went to Hong Kong by air the chances were that he would land in conditions which he did not like—and Mr Broadbent shared his apprehensions.

132. It should also be borne in mind that bad weather conditions in Hong Kong were associated with easterly winds. The 25% of low cloud and bad visibility to which he had referred were usually associated with an easterly wind and that was another reason for apprehension when landing on the south-easterly approach, since not only was it necessary to pass over the hills and then turn hard to the right, but it might have to be done in bad weather and without radio aids.

133. The original plan had been for a two-runway layout, with a runway from east to west as an extension of the original east–west runway, with its clear approach from the west (which was, as Mr Grace had said, the only clear approach to the airport), together with a new runway, planned roughly in the same direction as the one emerging from the later report. The decision taken by the consultants to move the new runway out to

sea had been a good one. The engineers had been able to prove that it was cheaper to build the runway out to sea than to build it on land. Mr Broadbent had been surprised when he heard of it, but land values were such that it paid to reclaim land in that way and to sell the old land. That assumed, however, that the old land could be sold.

134. He thought that it was a mistake to dispense with the second runway because a single-runway scheme might not work from an aviation point of view. In his view a second runway would be necessary since it would probably be found that the new runway would not be properly usable by large jet aircraft in both directions. A good attempt had been made, but such a runway might be dangerous, because if no other runway were available big aircraft would attempt to land on the curved approach. He was sure that that would lead to trouble.

135. The investigations which led to that decision were dealt with in § 12 of the Paper. The Paper indicated that the curved approach had been based on a rate-1 turn for an aircraft flying at 120 knots. The radius of that turn was 4,000 ft, and he assumed that the curved approach was based on that figure. The new runway, however, had presumably been planned not only for small aircraft but for the large jet aircraft of the future, and they would not approach at 120 knots. Three weeks previously he had flown in a Boeing 707 and had landed at Seattle in bad weather. He had been in the pilot's seat. Referring to his diary, he found that the wheels had been put down at 200 knots, the initial approach started at 180 knots, with 20° of flap, and the main approach at 160 knots, with 30° of flap. When the runway had finally been in sight, approximately 4,000 ft away, the conditions had been full flap and the speed reduced to 140 knots. The touch-down had been at 120 knots. That was with one of the new jet aircraft for which, presumably, the new runway at Hong Kong had been planned, and the speed for the main part of the approach, a straight-in approach, had been 160 knots. At that speed a rate-1 turn gave a radius of over 5,000 ft, not 4,000 ft, so that he would suggest that even on a basis of theoretical calculations it would be necessary to knock a few more hills down.

136. He was quite serious about that, because he thought it was very important. He suggested that the consultants should have another look at the curved approach. The figures which they quoted would not apply to the new jet aircraft. They would have to widen the curved approach if it was going to work at all for those aircraft, but he thought that with the bad weather which was prevalent, and the fact that 73% of the landings, even assuming a 20-knot cross-wind component, would take place over the curved approach, because the winds blew from the east, there would be a strong case for a straight approach with an east–west runway. He suggested that they should not burn their boats so far as an east–west runway was concerned. The present plan was to build the terminal area on the site of the existing 07/25 east–west runway which provided the only good approach to the present aerodrome. That, he submitted, was an error. Even if the second runway were not built now, it should be kept in reserve and its site not prejudiced for all time, because the single-runway layout with the curved approach might be found unusable by the big jet aircraft of the future, and Hong Kong would be by-passed by them.

Mr W. R. Rangeley (A Senior Engineer of Sir Alexander Gibb & Partners), referring to the cost of £7,000,000, said he thought that a great deal of that must be for the sea-walls, and he would be grateful if the Authors would give the proportion of the cost attributable to them. Mr Grace, in presenting the Paper, had said that it was cheaper to reclaim land, for the purpose of building the airport, than to buy it. That provided food for thought, especially in view of the fact that in reclaiming land for a runway structure the land was being reclaimed relatively uneconomically. It meant having a reclaimed area going out to sea like a pier, with expensive sea-walls on each side. It seemed to him that there might have been an excellent opportunity to reclaim land on a much wider and probably very profitable scale. It seemed that by closing the gap on the north-east, between the mainland the south-east end of the runway, the length of the sea-wall would have been reduced and excellent opportunity provided for the reclamation of Kowloon Bay, or at least for its partial reclamation.

138. Could the Authors add to what was stated in the Paper about the facts which led to the adoption of the single 60,000-lb wheel-load as well as the dual-tandem four-wheel load? In the Authors' opinion, did the modern trend in aircraft design justify that decision?

Mr C. F. Hoare (Superintending Civil Engineer, Air Ministry) said there were two small points which he would like to raise. It was stated that airliners using the existing airport suffered a pay-load penalty owing to restrictions caused by the runway approaches. He assumed that aircraft taking off from the new runway would not be subjected to the same penalties, and that the penalties would be minimized or cut out altogether; but with Manilla, as a diversion airfield, about 700 miles away he felt that aircraft flying into the new runway would still be subject to some form of restriction on pay-load.

140. Two alternative sites in the New Territories were shown in Fig. 1, Plate 1. Probably past records would show whether bad weather conditions at Kai Tak would also stop flying in the area of Deep Bay or Ping Shan. Had any consideration been given to the development of, say, Ping Shan as a diversion airport in the future, so that airliners flying into Hong Kong would not be subject to pay-load restrictions owing to the possibility of being diverted 700 miles to Manilla?

141. Secondly, there were two densely-populated areas, Kowloon and the city of Victoria, separated by Hong Kong Harbour. If it did not exist already he was sure that in the future there would be need for a helicopter service between the two centres of population. Had the Authors considered providing helicopter facilities in the vicinity of Kai Tak? Presumably such facilities should be on the south-west side of the new airport site to avoid the flight paths of airliners and helicopters crossing each other, and that area at the moment seemed to be fairly crowded.

Mr John Alston (Superintending Civil Engineer, Ministry of Transport and Civil Aviation) said that in § 74 the Authors gave as one of the reasons for selecting initially a fairly high design loading the interruption to air services which would be caused if further strengthening were necessary of a runway which was in use. He did not see any insurmountable difficulties in that since if a runway having an L.C.N. of, say, 50 to 60 were constructed at the present time, further strengthening would involve a black top of 1½ in. or so, which could be carried out over half the runway width at a time, the aircraft using the other half. Alternatively, schedules could be grouped together to allow 4 or 5 hours of surfacing and an hour or two for the surfacing to harden. In any case the problem would have to be faced at some time in the future.

143. In § 76 a 4½-in. black top had been specified. He felt it might have been prudent to lay a 3-in. or 3½-in. asphalt carpet in the first instance which, if his information was correct, would cater adequately for the aircraft likely to use Hong Kong for the next few years, and for the relatively few operations of Boeing 707s and D.C.8s which would be effected up to, say, 1961, and then add a further thickness, making 4½ in. in all, in, say, 1961. The opportunity could then be taken to iron out the differential settlement which he felt might be more than a possibility in a job of the kind in question, bearing in mind the very narrow permissible limits of variation of level demanded by modern aircraft.

144. In § 76 the Authors assessed a basecourse thickness of 12 in. for the runway, which would indicate, on the basis of Fig. 14, an assessed C.B.R. value of more than 20% for the fill. At the present stage was there any further information on that point?

145. It was not clear from the Paper why a tire pressure of 250 lb/sq. in. had been specified when the highest tire pressure of any civil aircraft yet built or under construction was, to his knowledge, less than 160 lb/sq. in. A 60,000-lb single wheel-load at 160 lb/sq. in. would give an L.C.N. requirement of under 80, which would be slightly in excess of the D.C.8's needs for the airfield if a C.B.R. of 20% + was achieved on the fill.

The Authors, in reply, said that they were interested to learn from the Chairman that the airport site had been originally developed for housing, a use to which much of it

would now be put 30 years later. The Chairman was quite correct in saying that the most important factor in siting the runway was to place it far from the hills, and the cost of reclaimed land relative to the value of land on the existing airport made such a siting economically possible.

147. The holes shown in Fig. 7 (p. 287) were relatively shallow trial pits, dug by hand. They were taken to only 6 ft since that was considered an adequate depth for assessing the strength of the runway foundation. These particular trial holes lay within the area developed by the Japanese during their occupation; the shelly sand to which the Chairman referred was found in similar trial holes further to the east, but these were not reproduced in Fig. 7, since they did not come within the boundaries of the new terminal area.

148. Replying to Professor Skempton they said that they had been fortunate with the investigation in that they had been working in an area where appreciable civil engineering work had been carried out before. That had presented the opportunity to check the laboratory test results by the analysis of the stability of an existing structure. Results obtained in that way were, in the Authors' opinion, always more reliable than those obtained in the Laboratory.

149. A piston sampler had been used, but only in the soft silt overlying the sands and clays. For the sampling of the clay strata a standard type of sampler was recommended in Civil Engineering Code of Practice No. 1 (1950), but with a sharper cutting edge, had been used.

150. Professor Skempton had asked for further data on the clays. The strata beneath the silt, derived from granite in various stages of decomposition, were very varied in character, ranging from coarse sands to plastic clays, and there was no apparent correlation between shear strength and depth. A typical abbreviated boring record was shown in Table 4.

151. Other typical classification test results, for forty samples taken from twenty-seven different borings made towards the end of the investigation, were summarized in Table 5. These samples were mostly described as sandy clays, silty clays, and clays.

152. Properties of the materials to which Fig. 11a referred were shown in Table 6.

153. Those samples showed no correlation between c/p and plasticity index. Four of the above triaxial test results plotted below Professor Skempton's line (Fig. 21): of those, three (Nos 6, 7 and 8) were grey silty clays which were not really typical, while the fourth (No. 9), a sandy clay, was only very slightly below the line.

154. In a further attempt to obtain a relationship between c/p and plasticity index, most of the materials described on the boring records as "clays", without the qualification "sandy" or "silty", had been reviewed. They had occurred in about 1 in 5 of the borings, and samples had been taken and fully tested from about one-third of them. Of eleven samples taken from depths of less than 20 ft below the sea-bed, all but one had given c/p-values greater than unity: while of seven samples taken from depths of 20-ft or more, all but one had given c/p-values of less than unity. Test results for the deepest nine of the clay samples were as shown in Table 7.

155. Those were all above (mostly considerably above) the line in Fig. 21, and showed no consistent relationship between c/p and P.I. It appeared, therefore, that the conditions under which the material in Kowloon Bay had been deposited were different from those to which Fig. 21 related.

156. Although the Authors were satisfied that the investigation enabled a reasonable estimate to be made of the in-situ strength of the clay, it was not clear why the normal testing procedure produced such erroneous results. They thought that the discrepancy arose primarily from sampling disturbances, but they agreed with Professor Skempton that further investigation was required on that point.

157. Mr Lloyd Jones had inquired about the usabilities of the alternative sites. The Authors had no definite figures but would say that the usability of the Ping Shan and Deep Bay sites would be higher than the site chosen because of the better visability; the stone-cutters site would have been subject to the fogs in the Western Harbour, but straight approaches and radio aids would have done much to overcome that. He was correct in saying that many factors entered into the ultimate choice of site, and it had not been

TABLE 4.—DATA FROM BOREHOLE NO. S.B. 233

(Sea-bed level: 6 ft below Port Datum)

Depth below Sea-bed	Description of of stratum	Shear strength lb/sq. ft Vane*	Shear strength lb/sq. ft Triaxial†	Other data
0′ 0″ to 10′ 3″	Soft grey silty clay	—	—	—
10′ 3″ to 11′ 3″	Firm grey-brown sandy clay	>1,800	—	—
11′ 3″ to 14′ 6″	Soft-firm grey brown sandy clay	700	—	—
14′ 6″ to 16′ 9″	Firm brown sandy clay	—	—	—
16′ 9″ to 20′ 6″	Soft grey-brown sandy clay	1,050	780	M/c.: 28%. Dry dens.: 91 lb/cu. ft. L.L.: 47%. P.L.: 22%. Gravel: nil. Sand: 30%
20′ 6″ to 27′ 9″	Medium brown clay, sand, and pebbles	—	—	—
27′ 9″ to 29′ 0″	Soft-firm brown sandy clay	—	—	—
29′ 0″ to 36′ 0″	Medium-coarse brown clayey sand	>1,800	—	Dry density: 106 lb/cu. ft
36′ 0″ to 41′ 6″	Soft-firm pink-grey sandy clay	1,020 1,590	840	M/c.: 20%. Dry dens.: 105 lb/cu. ft. L.L.: 81%. P.L.: 22%. Gravel: 19%. Sand: 38%
41′ 6″ to 44′ 6″	Compact coarse pink clayey sand	>1,800	1,510	M/c.: 18%. Dry dens.: 107 lb/cu. ft Gravel: 46%. Sand: 30%
44′ 6″ to 51′ 9″	Very soft pink clay and soft brown-pink sandy clay and soft pink clay	1,110 1,560	1,555	M/c.: 31%. Dry dens.: 91 lb/cu. ft. L.L.: 48%. P.L.: 22%. Gravel: nil. Sand: 31%
51′ 9″ to 53′ 0″	Medium brown clay, sand, and pebbles	—	—	—

* Vane could not measure strengths above 1,800 lb/sq. ft.

† Consolidated to overburden pressure; undrained while shearing.

TABLE 5

	Max	Min	Average
Natural moisture content: %	47	16	27
Dry density: lb/cu. ft	118	76	98
Liquid limit: %	81	23	46
Plastic limit: %	33	14	20
Plasticity index: %	59	9	26
Passing No. 200 B.S. sieve: % (17 samples)	67	17	34

TABLE 6

Item No.	Borehole	Depth of sample below sea-bed: feet	Shear strengths, c: lb/sq. ft		Eff. overburden pressure, p: lb/sq. ft	M/c %	L.L. %	P.L. %	P.I. %
			Vane	Triax.					
1	N.P.	7	1,110	648	420	27	43	19	24
2	N.P.	17½	1,530	1,044	1,030	37	60	23	37
3	SH.1	33	875	390	1,650	27	32	14	18
4	SH.2	24	1,470	672	1,110	34	50	19	31
5	SH.2	39	1,290	732	2,010	31	35	17	18
6	SH.3	29	445	220	1,280	52	67	28	39
7	SH.4	26	500	177	1,140	52	69	27	42
8	SH.4	38	570	360	1,730	46	62	27	35
9	S.B. 232	40	1,050	585	2,400	28	57	20	37
10	S.B. 234	9½	1,200	769	400	18	57	22	35
11	S.B. 234	36½	960	806	2,020	28	47	18	29
12	S.B. 235	7½	850	598	380	20	38	20	18
13	S.B. 237	28	860	696	1,400	30	65	27	38
14	S.B. 239	21¼	1,010	362	1,090	20	23	14	9

possible to refer to all of them in a Paper covering essentially the operational and engineering aspects. In the circumstances, the choice was bound to be a compromise, and in the Authors' opinion the best compromise had been found.

158. The remoteness of the Ping Shan and Deep Bay sites contributed to their rejection. Although only about 30 miles from Kowloon, the narrow, twisty, mountain roads reduced the average speed for a private car to little more than 20 m.p.h. There was a scheme to lay a branch line of the railway to Deep Bay, but that railway was single line and times on it were much the same as for road travel. During the past 6 months, 51% of passengers had made short journeys to Okinawa, Formosa, the Phillipines, Vietnam, Bangkok, and Rangoon, a further 33% had made medium journeys to South Korea, Japan, Singapore, and Borneo, and the remaining 16% had made long journeys, of which 4½% were to Europe. Should air communications with China re-open, the percentage of short-haul

TABLE 7

Item No.	Borehole No.	Depth of sample below sea-bed: feet	Shear strength, c: lb/sq. ft	Eff. over-burden pressure, p: lb/sq. ft	L.L.	P.L.	P.I.	c/p
1	S.B. 31	18	330	860	76	28	48	0·38
2	S.B. 207	19½	1,515	810	82	26	56	1·87
3	S.B. 215	20	180	850	39	18	21	0·21
4	S.B. 77	21	2,100	900	78	23	55	2·33
5	S.B. 214	23	630	1,090	47	19	28	0·58
6	S.B. 220	34	540	1,710	52	20	32	0·32
7	S.B. 214	44	1,170	2,350	66	23	43	0·50
8	S.B. 233	46	1,110	2,560	48	22	26*	0·43
9	S.B. 233	52	1,560	2,920				0·53

* Taken from a more sandy intermediate layer.

traffic would increase. Travelling time between the city and airport was therefore, important, and perhaps particularly so for the many tourists who now stopped over for a night or two.

159. Mr Lloyd-Jones enquired about radio aids. That all-important subject was being handled directly by the Department of Civil Aviation of the Hong Kong Government, who informed the Authors that it was proposed to install the most advanced aids that could operate successfully on the site. Long-range surveyance radar was to be used for separation of aircraft at 300 miles range and to control their initial descent. G.C.A. medium-range surveyance and precision-approach radar was to be used from 50 miles, and there was good reason to expect that an instrument landing system could be installed satisfactorily on the south-east approach. Naturally, the aids that could be used on the curved approach were limited, but that limitation could be overcome in part by the use of built-in radar screens, as at present fitted to the Britannia and to be fitted to the American jet airliners. The Authors were informed that when the Britannia had landed in Hong Kong in February 1957, the hills in the approach through Lei Mun Gap had shown clearly on the screen. Future developments in that sphere might materially improve the problem of landing in Hong Kong in poor visability. In the Authors' view, breakaway to the west following an instrument approach through Lei Mun Gap should not present any great difficulty. It would be made over a beacon, and the highest ground in the vicinity of the breakaway path was 400 ft. In many cases the visibility to the west of the airport was better than in the south-east approach.

160. A runway width of 200 ft had been considered advisable because of the occasional high cross-wind landings that would have to be made on it. The length of runway required for take-off was not only the length necessary for an aircraft to become airborne, but also the length for it to decelerate and stop should trouble develop before it became airborne. That was known as the accelerate/stop distance. More specifically, the accelerate distance was that required for the aircraft to reach the critical velocity, which was the velocity at which it could safely climb away on the take-off path in the prevailing weather conditions with one engine cut. The stop distance was that required for the aircraft to decelerate from the critical velocity to a standstill. The accelerate distance was generally less than twice the stop distance, so that an aircraft requiring the full runway for accelerate/stop was usually airborne within two-thirds of the length of the runway; the remainder of the runway was only used as a stop distance but was a necessary provision in case of emergency. The full length of paved runway could be used for accelerate/stop. unless obstructions in the take-off path made it impossible for an aircraft to clear them by an adequate safety margin when taking off as defined above with one engine cut. In

that case the take-off weight of the aircraft should be decreased and the accelerate/stop distance required by the aircraft reduced accordingly. The Authors understood that that restriction would not apply in that case, so that the full 8,340 ft would be available for take-off to the north-west just as it would be for take-off to the south-east.

161. The official definition of take-off distance was given in Article 39 (b) of the Air Navigation (General) Regulations 1954 and from that it could be seen that the take-off distance to the north-west was at least 8,340 ft.

162. It was originally intended to design the pavements to carry aircraft with an all-up-weight of 200,000 lb. which was then considered to be the likely maximum weight of aircraft for the next decade. Recently, however, figures have been published for the new American jet airliners with all-up-weights of almost 300,000 lb. It was common for successive series of an airliner to be progressively heavier, and to cater for that new generation of jet airliners it was considered advisable to design for an all-up-weight of about 350,000 lb. An analysis of the runway at the new Paya Leba Airport in Singapore had indicated that it could take aircraft weighing 300,000 lb. The great majority, if not all, of the older civil airports in the East should be strengthened if they were to take those jet airliners. Until the maximum weights of aircraft were restricted by International agreement, there could be no uniform basis of design for airport pavements.

163. Dr Golder had expressed fears concerning the safe operation of aircraft on the curved north-west approach, and the Authors would comment on that in their reply to Mr Broadbent's remarks. The airport should be open day and night, and a comprehensive lighting system was to be installed. The extent to which aircraft would be scheduled through Hong Kong at night was not yet known, but a number of airline companies had expressed their intention of using the airport by night.

164. The undisturbed samples of sand from the dredging area had been taken to provide the contractors with accurate information on the sand to be dredged. Those undisturbed samples had been placed in an exhibition available for the contractors before submitting their tenders. The contractors could, therefore, examine the sand in the same state as it had existed in the bed of the harbour.

165. The technique of obtaining undisturbed samples of sand had taken some time to develop but once it had been perfected the cost of undisturbed samples of sand was little more than the cost of obtaining undisturbed samples of clay.

166. Dr Golder considered that further effort should have been made to resolve the anomaly of the vane and triaxial test results. In the Paper, which covered a wide field, it had been possible to devote limited space to that matter, and the Authors would like to enlarge briefly on that aspect of the work. The main problem confronting the Authors as Consulting Engineers had been to obtain a reliable estimate of the in-situ strength of the clay. The problem had been resolved to their satisfaction. The problem of the discrepancy between the vane and the triaxial tests was, in the Authors' opinion, one primarily for the research establishments. The Authors appreciated its importance, and had spent appreciable time and effort in studying it. One fully qualified engineer had been detailed to give his full time to resolving the difference. The University of Hong Kong had been called in to assist with the investigation. The work undertaken had shown that when the degree of disturbance in the samples tested was the same and the maximum possible, the results of the vane and triaxial tests agreed. That indicated that the testing machines were being correctly operated and that the discrepancy lay elsewhere. Further vane tests had been carried out on the so-called undisturbed samples in the laboratory, before they had been removed from the sampling tube, but an insufficient number of results had been obtained to draw any conclusions.

167. As mentioned before, the piston sampler had been sampled by the standard sampler as recommended in Civil Engineering Code of Practice No. 1. That was the standard type of sampler used in the United Kingdom and had an area ratio of 23%. The Authors believed that appreciable disturbance was caused by samplers of that type and that sampling disturbance was chiefly responsible for the difference between the vane and the triaxial results.

168. Dr Golder had asked about the presence of lenses of silt and sand. The test

results had shown that the clay contained varying percentages of silt and sand, but they were usually reasonably evenly distributed throughout the clay. Undisturbed samples had at times been taken of clay which had previously been tested by the vane apparatus, but in no case had lenses of silt or sand been detected.

169. Dr Millard had inquired about the reactions of those living in the densely populated area through which the access route for the hill excavation passed. The Authors' firm had originally recommended a longer route, by-passing that area, but there had been difficulties in land compensation, and it was the Hong Kong Traffic Police who had suggested the direct route through the built-up area. The route was fenced for its full length, with 24 ft centre-to-centre of fencing, it over-passed public roads at two points, and ten footbridges were provided for pedestrians. It was quite remarkable how successful the route had been. The contract had specified that all earth and other material dropped from the contractors' vehicles should be promptly removed. There were some initial complaints about loss of business and dust. The latter was overcome by continuous watering of the route, and the Chinese soon accepted the inconvenience and with characteristic ingenuity adapted their methods of business to the new conditions. It was doubtful if any other people would have reacted so well to such a disturbance of their daily lives. The route was the shortest possible but vehicles using it have had to be restricted to an overall weight of 10 tons, to conform with the Traffic Ordinance. It had been feared that heavier vehicles might cause damage to buildings which would result in claims for compensation.

170. Concerning settlements, Dr Millard appeared to have credited the Authors with more ingenuity than they deserved! The total ultimate settlement had been estimated in the normal manner by calculating the additional stresses set up in the deposits by the weight of the reclamation and applying the results of consolidation tests on uudisturbed samples. The large and relatively wide reclamation would cause additional stresses to be set up in the foundation to a considerable depth; even at depths of 500 ft and 1,000 ft the additional stresses were estimated to be 7% and $2\frac{1}{2}$% respectively of the stresses existing in the ground before the reclamation was formed.

171. The borings and undisturbed samples could be obtained only from depths of less than 100 ft and, therefore, the estimates of settlement depended on a number of assumtions concerning the nature of the strata beneath the 100-ft depth. The greater proportion of the settlement would arise from consolidation in the upper layers of the deposit, but, as stated in the Paper the Authors considered that it was only possible to generalize on the possible magnitude of the ultimate settlements.

172. The rate of settlement was a different matter. That depended on whether or not excess pore pressure could escape from the strata of sands which were intermingled with the clays. No one could say with any certainty which sand strata were free draining and which existed as lenses entirely enveloped by clay. It was, therefore, impossible to make any estimate of the rate of settlement of those underlying strata.

173. A maximum fines content of 25% in sand under pavements was chosen after study of the samples taken from the dredging area and the likely quantities of sand available. With up to 25% fines, the material was basically a coarse sand that would settle rapidly. The majority of the material with a higher fines content was appreciably finer and basically a silt or clay; in practice, the dividing line of 25% has worked well, it being a relatively easy matter to distinguish between material meeting or failing that requirement. The likely quantities available also indicated that there would be space in the shoulders to accommodate the volume of material with excess fines that would have to be dredged to obtain better quality sand. If an upper limit of, say, 20% had been adopted it was probable that an appreciable quantity of dredged material would have had to be dumped to waste. No amendment had been made in the specification to reduce the fines content in the upper layers to 15%, but above a level of about −4 Principal Datum the sand was being pumped, and the fines were, of course, being washed out in the process. A maximum of 15% fines for the sand in the seawall trenches was specified for strength considerations as mentioned in § 61.

174. The sand had been classified by the barge load. Samples were taken as the barge

filled, and a final representative sample was subjected to a rapid fines-content test carried out on the dredger. There was also constant visual inspection of the dredged material. The system, which would be more fully described in the Paper on the Construction of the Airport, was working well.

175. The loose state of the decomposed granite foundation on the existing airport was probably because of sabotage, since hitherto the practice in the Colony had been to end-tip the material without any attempt at controlled compaction. As could be seen from the note on Fig. 8 (p. 290), the general run of decomposed granite had a medium to high plasticity, and its strength was sensitive to moisture change. The Authors agreed with Dr Millard that it would have to be well compacted if it was not to require an uneconomic thickness of base course overlying it. There should be no difficulty in attaining a high degree of compaction in the dry season, but during the rains moisture control during construction was extremely difficult. To obtain an adequate depth of compaction, the top 2–3 ft would have had to be dug out and recompacted in layers. The crux of the matter, however, would be the equilibrium moisture content that would be built up in the decomposed granite. The underside of the base course was only about 7–10 ft above the water table, and moisture-content tests under pavements had shown that with loose decomposed granite the moisture pick-up could be considerable. No tests had yet been made in Hong Kong on the material in a dense state. The Authors were interested to hear Dr Millard's opinion that any subsequent wetting-up would not produce great reductions in bearing strength. There was, however, an advantage in founding the base course on sand throughout the airport, since any future strengthening would have required the same treatment for all pavements, and the Authors favoured a depth of non-plastic sub-base which they thought proved to be the most economic solution.

176. The tender documents included alternative designs for the base course; a 12-in. layer of crushed stone, and a 7-in. layer of stone macadam overlying 5 in. of soil-cement. In the latter the cement content was to be about 10%. The decision to adopt the crushed stone base course had been taken after receipt of tenders, since that was much the cheaper form of construction.

177. The runway was to be drained at its sides by slotted channels from which surface water would be piped to the edge of the reclamation. The 20-ft strips of sand on either side of the runway would be covered by 1 ft of decomposed granite, to support the growth of grass. It was unlikely therefore that any appreciable quantity of surface water would have found its way into the sand foundations of the runway. Any that did could escape through the lower layers of the shoulders, which being uncompacted would be relatively pervious, or through the sand foundations of the link tracks joining the runway and the taxiway.

178. Mr Tomlinson's reference to disturbance of samples caused by movement of the casing did not apply. A piston sampler had been used only for sampling the silt, and for that no casing had been used, the sampler having been attached to a rod which was pushed down by hand to the required depth; the rod had not been attached to the boring barge. When sampling the underlying strata, the borehole had been cased. The casing had sunk under its own weight to the underside of the silt, after which it had always had to be driven, without support by the barge. Samples had in every case been taken below the level of the foot of the casing.

179. Mr Tomlinson had raised the important issue of the contractual risk in obtaining adequate quantities of suitable sand from the dredging area. He was correct in saying that the deposits in the dredging area were mixed, but nevertheless the fifty boreholes in the area had clearly demonstrated certain tendencies. First, the surface layers, particularly in the shallower water, contained a high proportion of fines; secondly, the quality of the sand improved progressively with depth; and, thirdly, there were areas that were likely to yield good quality sand for the full dredging depth, just as there were other areas, mainly to the north of the dredging area, which would require excessive stripping of poor quality material so that limited quantities of good sand could be obtained. Those tendencies had been borne out in practice. A comparison of Table 3, which listed the quantities of materials required, with Fig. 9, which gave the quantities of materials available, demon-

strated that adequate quantities could be obtained provided that dredging was carried to a sufficient depth. The problem then became one of selection during the dredging process. Mr Tomlinson was incorrect in saying that the material had to be pumped to the reclamation. The most obvious and economic method of conveyance was by barge. With an allowance of 450,000 cu. yd for settlement, and assuming that 2,500,000 cu. yd of soil from hill excavation would be included in the fill in the shoulders, about 8,300,000 cu. yd of dredged material was required in the reclamation. By using 500-cu.-yd barges, the successful contractors had in effect divided the dredging area into 16,600 units, each barge load or unit having been classified into one of the three categories of fill specified. That in itself had been a relatively simple matter, and the main problem had been to obtain the various categories in the right order, and in particular to avoid the necessity of dumping to waste material with a high fines content for which space was not available in the shoulders. That difficulty had in the main been overcome by moving dredgers to areas of good or bad sand as indicated by boreholes and required by the construction programme, and by avoidance of areas likely to yield a disproportionately high quantity of poor material.

180. The cope level of the seawalls was somewhat higher than the majority of other walls in Kowloon Bay, and it was to be built up a further 3½ ft at the seaward end of the reclamation to withstand waves from the direction of Lei Mun Gap. Those were expected to be the highest that would strike the promontory and would occur shortly after the centre of a typhoon had passed to the south of the Colony. Records had been studied of the effect of typhoons on tide levels. The general sea level rose by a maximum of 1 ft, owing to a reduction in the atmospheric pressure, and in addition there was a build-up caused by the wind. That could be appreciable along the open shores of the Colony, but the narrow inlets of Kowloon Bay reduced its effect there. Precise figures were not available but for an average typhoon the rise from wind was probably 2–3 ft. When a typhoon corresponded with a spring tide, there was no doubt that the waves would overtop the seawall, but the top of the exposed wall was paved for 15 ft and it was unlikely that there would be any appreciable scour on the shoulders. The edges of the runway was 4 ft above the level of the sea wall and 250 ft from it, and should escape all the effects of a typhoon.

181. The shear strength of the silt varied, and the figure of 100 lb/sq. ft was an average strength determined by the unconfined compression test. Taking that figure and a submerged weight of the silt of 40 lb/cu. ft the Authors calculated that a 1-in-2 slope, 20 ft deep, gave a factor of safety of just greater than unity. The silt had additional strength owing to internal friction. In practice the silt had stood up at varying slopes, and quite frequently at about 1:1.

182. The Authors considered that it was quite impossible to generalize on the cost of a site investigation, since everything depended upon the nature of the project. The site conditions and other circumstances revealed during the investigation. The figure of £70,000 or about 1% of the overall estimate for the airport covered the cost of the borings necessary for the preparation of a contract, but only the cost of preliminary soil testing and design undertaken for the report stage. An investigation for an airport on land would almost certainly have been appreciably cheaper, although the percentage cost might well have been higher.

183. The engineering aspects of the scheme were incidental to its operational success, and Mr Broadbent's criticism was therefore a fundamental criticism of the project. He had stated that a single runway layout would not work from an aviation point of view, that the new runway would not be properly usable in both directions, that it might be dangerous and would lead to trouble, that the closure of the present east-west runway was a serious error, and that Hong Kong would be by-passed.

184. His criticism was based in part on incorrect or misleading facts, and his general conclusions were at variance with the views of the authorities who had been constantly and intimately connected with the scheme, including the Department of Civil Aviation of the Hong Kong Government, the Ministry of Transport and Civil Aviation, the major airline operators and the aircraft manufacturers.

185. On matters of fact, Mr Broadbent's remarks erred in the following respects. Firstly, he had stated that the incidence of bad visibility of less than 3 miles and cloud

base below 800 ft was 25% whereas the Royal Observatory's figure, reproduced in the Appendix, was 7%. It was relevant to mention that Hong Kong-based airlines operated on the existing airport with weather minima of 2 miles visibility and 500 ft cloud base, and the Department of Civil Aviation expected that those, or even lower, minima would apply to the new airport with improved approaches, airport lighting, and radio aids. The effect of bad visibility on the new airport would not, therefore, be so severe as indicated by Mr Broadbent.

186. Secondly, Mr Broadbent had stated that because of the prevailing easterly winds 75% of landings would have to be made on the curved north-west approach. A tail-wind component of 5 knots could be accepted for landings and, using that figure, 67% of landings would be made from the south-east, leaving only 33% to be made on the curved approach.

187. Thirdly, Mr Broadbent had stated that the low cloud and poor visibility to which he referred were always associated with an easterly wind. In general they were, but in those conditions the winds were nearly always so slight as not to affect the direction of landing. Bad visibility was caused mainly by sea mist and fog which drifted across the harbour area, and any strength of wind rapidly dispersed them.

188. Mr Broadbent had referred to passing over hills before making the turn on the curved approach. That point had also been mentioned by Dr Golder earlier in the discussion who had gained the impression that the airport could not be seen until the very last stages of the approach. The hills in the immediate approach were to be excavated to the level of the houses, giving a 1-in-40 approach surface. Beyond that the highest hill in the approach was 325 ft, at a distance of about $2\frac{1}{4}$ miles from the runway. It would, therefore, be possible for an aircraft on that approach to let down to 500 ft over the sea, and fly in at that altitude. The normal approach would be made at an angle of glide of 4° and, there being no obstructions on the inside of the curve, the runway would be visible to a pilot before he crossed the western shore of the Kowloon Peninsula, about 3 miles from the runway. The film had given a misleading impression of that approach, since the camera had a relatively narrow-angle lens and had been fixed in the aircraft. As could be seen from Fig. 3, there was a great deal of air space available for the landing. The only real obstruction was the range of hills to the north of the approach, and an aircraft would have to be far off course to become dangerously close to them. In bad visibility aircraft would first pick up an airport beacon near the western shore of the Peninsula, and then would be led by high-intensity lights to the curved approach and the runway.

189. Mr Broadbent was correct in stating that the curved approach had been originally designed for an approach speed of 120 knots, and that figures recently made available showed that the new jet airliners would approach at higher speeds. The radius of the curve had been increased to 5,000 ft to conform with a rate 1 turn at 160 knots, if aircraft of the future required that approach speed. The increased radius had been affected without any significant alteration to the hill excavation, but the length of final straight run in to the landing threshold had been reduced from 3,000 ft to 2,800 ft.

190. The Authors hoped they had demonstrated that the incidence of bad weather landings, the number of such landings necessary on the curved approach, and the obstructions and difficulties on that approach were all far less than indicated by Mr Broadbent. There remained his final conclusion that large jet airliners would not be able to operate on the curved approach, and that Hong Kong would be by-passed by them. As already stated, the Authorities intimately connected with the scheme did not hold the same opinion. Plans of the new airport and the curved approach had been widely circulated. Pan American World Airways had sent to Hong Kong numerous representatives and technical advisers, including General Lindberg. They had had practical experience of flying the Boeing 707 and had written to the Director of Civil Aviation, Hong Kong, stating that they expect the approach speed of that aircraft and of the D.C.8 on the curved approach to be 130 knots. Representatives of the design staffs of the Douglas and Boeing Aircraft Companies had inspected the site, and had pronounced themselves satisfied. The former had written saying that they had assumed an approach speed on the curve of 139 knots, and that for non-instrument conditions they did not consider either the angle of bank

or rate of descent to be excessive. The British Overseas Airways Corporation were satisfied that the Comet IV and the Britannia could operate on the single-runway layout. Mr John Cunningham, the Chief Test Pilot of the de Havilland Aircraft Company, had written to the Director of Civil Aviation confirming that the proposed radius of turn for landing on the new runway would present no difficulty to a Comet IV. He had assumed an approach speed of 130 knots on the curve with a bank angle of approximately 16°, which he considered quite feasible. In February 1957, the Britannia had landed on the curved approach to the existing 13/31 runway, and scheduled services with that aircraft were to be flown from the existing airport from July 1957. There seemed to be no doubt that the next generation of airliners could and would operate on the new runway.

191. That being so, the only advantage to be derived from the retention and development of the present east-west runway would be a small increase in the usability of the airport. The lighter types of aircraft, susceptible to cross-wind landings, would have an additional landing direction which would probably save a few diversions throughout the year. However, the tendency in aircraft design was for all types to land safely in progressively higher cross-winds, so that in the long run there would probably be little to gain on that account from the additional landing direction. At present it was questionable whether large jet airliners could be brought in to land on a straight approach to a dead-end runway in poorer visibility than on a curved approach to a two-way runway. There were inherent dangers in a dead-end runway resulting from the fact that beyond a certain point the aircraft was commited to land. One well-known authority had informed the Authors that in the future it would be possible, with improved radio aids, to fly the curved approach blind, in which case that landing would be preferable to an instrument approach on a dead-end runway.

192. It was relevant to mention that when wind and visibility on the present airport permitted landings to be made either on the curved approach to runway 13 or on the straight approach to the dead-end 07 runway, pilots preferred the former since overshoot on it was impossible.

193. To sum up, the retention and development of the present east-west runway would be of benefit operationally, but that benefit would be relatively small in the first instance and likely to diminish with time. On the other hand, the implications of retaining and developing the runway would be very considerable. If the runway were set in a strip 600 ft wide, it would occupy about 96 acres, and in addition a further appreciable acreage would be wasted, since many ill-shaped areas would be left that could not be developed, and the whole layout of the terminal and maintenance areas would become wasteful, and far less efficient. Only a fraction of the 140 acres to be released in the single runway layout could be released if the second runway were retained. Further, an appreciable area of land would have to be either sterilized or suffer building restrictions in the approach to the second runway, the R.A.F. station would be split in two, and the Kun Tong Road would have to be tunnelled beneath the runway. In the Authors' view, the relatively small benefit to be derived from retaining and developing the second runway in no way justified the very high cost and other implications involved in doing so.

194. The curved approach to the new runway would be very much easier and safer than the curved approach to the present 13/31 runway, and about 15,000 landings by civil airliners had been made on the latter without incident. There was, therefore, no cause for the air traveller to Hong Kong to feel anxiety about the approach to the new runway. Similarly, there was no cause to fear that future airliners would be unable to operate on the single runway layout, and the Authors were convinced that the decision taken by the Government of Hong Kong to adopt the present layout was fully justified.

195. Mr Rangeley had inquired about the proportion of the total cost of the airport attributable to the seawalls. That would be about 18%. The shape of the reclamation was uneconomic in view of the length of seawall, and the possibility of large-scale reclamation of Kowloon Bay had been considered. However, the Government of Hong Kong had not favoured it for a number of reasons. In the first place there were several large shallow inlets, some dry at low tide, that could be reclaimed more economically, and their locations outside the harbour area would help to decentralize industry and develop the New

Territories. Further large-scale industrial and domestic development in the harbour area would contribute to atmospheric pollution, and the new reclamation along the eastern shore of Kowloon Bay was to be on a limited scale. The stretch of water to the east of the airport reclamation would be used for flying boats and also for access to existing shipyards and future factories.

196. In recommending a design loading for an airport pavement, the Authors considered that an isolated wheel load should be included in the design criteria as well as the multiple-wheel loading of the critical aircraft for which the pavement was being designed. Although in the present trend of undercarriage design there was nothing to indicate a future load of 60,000 lb. on a single wheel, it was yet possible that with increasing tire pressures and spacing of wheels on multiple-wheel uudercarriages would be reduced and result in an equivalent isolated wheel loading of that figure.

197. Mr Hoare had raised the question of pay-load penalties. All known or projected British aircraft could take off from the new runway with their full loads, and would suffer no penalty of any kind. The manufacturers of the Douglas D.C.8 at present considered that the maximum take off weight for that aircraft on the new runway would be 280,000 lb. (about 20,000 lb. less than the maximum for the aircraft). That, however, did not necessarily mean that the pay load would have to be reduced, since the normal flight distances flown from Hong Kong were not great, and aircraft did not need to take on their full load of fuel. There would be a pay load penalty only if the aircraft were to fly direct to, say, Honolulu or Karachi, for which full tanks would be required. Should a later series of that type of aircraft be fitted with more powerful engines, it was probable that it could take off with its maximum weight.

198. The distance away of the diversion airport of Manila meant that aircraft flying to Hong Kong would either have to carry more fuel or hold for a shorter period over Hong Kong than if an alternate airport were nearer at hand. That, however, would not necessarily affect the pay load carried by the aircraft unless there were restrictions at the airport from which it had taken off. A second airport in the New Territories would be too close to be effective as an alternative, in view of the extent of bad weather in the Colony.

199. The Government of Hong Kong had decided not to make provision for helicopter services since the airport was so close to the city.

200. The Authors agreed with Mr Alston that it would be possible to strengthen the runway at a later date by adding 1½ in. of surfacing. Of the two alternative measures he had suggested for undertaking that work, the Authors felt sure that the Authorities would prefer to group schedules and close the runway for periods, rather than restrict aircraft to the use of half the runway width. The periods of closure would have to be during the day, since it was inadvisable to attempt to lay a wearing asphalt course by night, and, as stated in § 74, that would result in interruption to air services. There was also the financial aspect of laying the increased thickness of surfacing at a later date. There was no asphalting plant normally available in the Colony capable of surfacing a runway rapidly, and if the 1½-in. surfacing was postponed until 1961, it was likely that contractors and plant would have to be brought in from overseas. There was no doubt that to carry out the work at that date with intermittent hours of working and the attendant inconvenience would result in appreciable increased cost. For those reasons it had been decided to lay the additional surfacing thickness in the first instance, rather than 3 years later.

201. Mr Alston had suggested that the 1½-in. surfacing might prove useful in ironing out differential settlement. That would be so if the differential settlement took the form of surface irregularities due to consolidation of the crushed stone base and sand subgrade. The Authors had believed that they could eliminate that type of differential settlement by careful and thorough vibration of the subgrade and base. The type of differential settlement which might occur and over which there was little control was that due to the consolidation of the strata beneath the layer of silt. That differential settlement would appear on the surface of the runway in the form of long waves or undulations and not as surface irregularities. If remedial measures became necessary, the 1½-in. surfacing would be incapable of rectifying that type of differential settlement, since the amplitude of the undulations would amount to more than 1½ in. before they became noticeable.

202. The series of plate bearing and C.B.R. tests referred to in § 76 were shortly to be put in hand, and the Authors could not at the present time give any further figures on the strength of the fill. The sand was angular, and there had been no difficulty in obtaining the specified density. From inspection it appeared to be a thoroughly sound foundation and was likely to have a C.B.R. value in excess of 20%.

203. Regarding the tire pressures, it was known that present or projected civil aircraft employed tires with pressures of appreciably less than the 250 lb/sq. in. used in the design. However, the new Hong Kong airport would be a joint-user airport for civil and military aircraft, and there were a number of the latter having tire pressures of the order of 250 lb/sq. in.

204. The Authors hoped that the explanations given in the reply had adequately covered the questions asked. The main point which they considered called for further investigation was the discrepancy between the triaxial and vane test results. They had found an expedient solution to the problem of choosing between the sets of results, and the walls based on the vane results were showing no sign of movement apart from the anticipated settlement. They considered, however, that further research by boreholes and tests was called for to find a more satisfactory explanation of the discrepancy between the tests.

Further references

[5] L. Bjerrum, "Geotechnical properties of Norwegian marine clays". Géotechnique, vol. 4 (1954), p. 49.

[6] S. B. Hamilton, "The French civil engineers of the eighteenth century". Trans. Newcomen Soc., vol. 22 (1942), p. 149.

The closing date for correspondence on this Paper was 15 May, 1957. No contribution received after that date will be published in the Proceedings.—Sec.