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The construction of the new Hong Kong airport†

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Discussion

Mr E. L. Barron (Project Leader, Brandt & Odell, Consulting Engineers) wrote that in view of the Building Research Station's investigations into concrete pipe design it would be interesting to have full details of the bedding conditions adopted and the corresponding load factors taken by the Authors. What bedding conditions would the Authors now prefer, and what impact factor did they consider appropriate for aircraft wheel loading? Were the pipes also designed for the multiple wheel loading mentioned in the previous Paper? What were the factors influencing the choice of concrete pipe rather than corrugated metal pipe?

85. Further details of the concrete paving would also be interesting. What determined the 4½- or 5-in. thickness of sand-cement base? Were tests made on the subsoil or base to establish the design value of $k = 1{,}000$ lb/sq. in.? How did the average flexural and compressive strengths obtained for the pavement quality concrete compare with the design flexural strength? Upon what basis was the 370-ft expansion joint spacing determined? What safety factor was used on the stresses determined by the modified Westergaard formula and what allowance was made for temperature stresses?

86. Regarding the bridges over the nullah, what was the advantage of driving the piles from the original ground level rather than driving shorter piles after excavation and casting the piers in situ? With the possibility of encountering old foundations it seemed that there was considerable risk of finding the piles damaged or deviated too far from the vertical to be satisfactory as piers. In estimating the load-bearing capacity of the piles from driving records, what allowance was made for the reduction owing to subsequent excavation?

87. Finally, could the Authors elaborate upon their choice of a 4 in/hr storm curve for the drainage design?

The Authors in reply stated that tenderers were given the option of offering precast or cast-in-situ concrete pipes for drainage. The specification for the precast pipes was based on the Australian Standard Specification No. A.35—Class X pipes. These pipes were reinforced and were required to take a cracking load of 700–1,000 lb/sq. ft, and an ultimate load of 1,000–1,500 lb/sq. ft, depending on the diameter. Pipes complying with the specification were known to be manufactured in Singapore. The design for cast-in-situ pipes was such as to produce pipes of similar strength. The construction of cast-in-situ pipes was widely adopted in Hong Kong and suitable techniques of shuttering had been developed. However, in the event, the successful tenderer elected to use precast pipes and he set up a special spinning plant on the site.

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† Proc. Instn civ. Engrs, vol. 19, June 1961, pp. 157–184.

89. The pipes were in general supported with concrete bedding and haunching. The foundation was compacted sand, and sand was specified for backfilling up to 6 in. above the top of the pipe. The load factor might therefore be assumed to be 2·5–3·0. Flexible joints were used and the concrete protection was broken by a ½-in. thickness of joint filler at each joint. The justification for a concrete bedding depended on the design loading, on whether or not the pipe required special strengthening, and if so the cost of it; on the availability, character and cost of possible filling material, and on the reliance which could be placed on proper compaction of the filling. In assessing these considerations the recent work of the Building Research Station was clearly valuable, and it would now appear doubtful whether haunching above the 120° contact line was worth while. Otherwise the Authors could not make any general recommendation on the subject.

90. It was calculated that the strength of the pipes specified would be sufficient to withstand the 4-wheel undercarriage loading of 160,000 lb. The least cover occurred under the runway and, taking into account the spread afforded by the paving, an impact factor of 40% was obtained in these conditions. Off the runway, where a higher impact factor might be desirable, the cover was considerably greater and the loading on the pipes correspondingly less.

91. Concrete pipes were chosen in preference to corrugated metal pipes because of their greater durability.

92. A sand-cement base was constructed underneath the concrete pavements primarily for practical considerations; it served to correct levels, thereby avoiding waste of concrete, and provided a true surface on which the steel forms could be laid and positioned accurately. A depth of 5 in. was adopted for the concrete areas of the main runway; subsequently it was found to be possible to decrease this to 4½ in. for the terminal apron.

93. A series of plate bearing tests to measure the modulus of subgrade reaction of the sand sub-base was carried out at the same time as the tests described in §57 of the Paper. Values of the order of 600 lb/sq. in/in. were obtained on the sand sub-base and of the order of 1500 lb./sq. in/in. on the top of a crushed stone basecourse. On the evidence of these tests, a modulus of subgrade reaction of 1000 lb./sq. in/in., which was one of the values plotted in the Air Ministry standard curves, was regarded as appropriate. This was subsequently checked by conducting tests on completed sections of sand-cement base.

94. In order to determine the flexural strength to be used in the design of the concrete pavements a series of tests was undertaken to compare the flexural strengths, of various mixes of concrete already in use, with the compressive strengths of such mixes, and also to assess the build-up of flexural strength with time. Once the mix associated with the selected design flexural strength had been chosen, quality control was exercised by the use of compressive strength tests. The 28-day design flexural strength of 525 lb./sq. in. at 28 days was comparable to a 28-day compressive strength of 5,000 lb./sq. in. for the particular concrete mix adopted. The average 28-day compressive strength obtained from the control tests was 6,250 lb./sq. in., the range being 5,080 to 7,225 lb./sq. in.

95. The design thickness of 14 in. was determined by use of the appropriate Air Ministry standard curve, and the exact dimension between expansion joints in the concrete pavements of the terminal area was governed by the general arrangement this apron.

96. The nullah bridges had to be constructed in accordance with a tight time schedule, and simplicity and speed of construction were of prime importance. Driving the piles from the original ground surface avoided the difficulty of manoeuvring the piling frame in the relatively narrow nullah excavation, permitted the bridge decks, which were of flat slab construction, to be supported on the ground without elaborate formwork and enabled the capping beams to be constructed by placing formwork in a shallow trench dug round the piles. Building the decks and capping beams at ground level also facilitated the placing of concrete.

97. Borings on the bridge sites indicated that the old foundations in these particular areas were shallow and limited in extent. It was necessary to remove some obstructions prior to pile driving, and the piles were in fact driven without difficulty.

98. The load-bearing capacity of the piles was estimated from the results of tests on piles (one at the site of each bridge) carried out at the start of the work. Pile-driving formulae were calibrated against the results of these tests and were used to check the capacity of the piles driven for the bridges. No allowance was made for the reduction in load-bearing capacity after excavation for the following reasons:

(*a*) It was known that the piles had a good reserve of strength over the design load. The load tests showed that the ultimate load-bearing capacity of the piles was about $2\frac{1}{2}$ times the calculated maximum working load, and the latter would be a transient loading.

(*b*) The material surrounding the tops of the piles, which was subsequently excavated, was relatively loose decomposed granite which would have contributed little to the load-bearing capacity of the piles.

99. The choice of a 4 in/hr. storm curve was based on the following considerations:

(*a*) The rainfall intensity records for Hong Kong over a period of 11 years corresponded approximately with the U.S. supply curve[1] 3·5 for storms lasting over one hour. For shorter storms the recorded intensities fell below this curve but the siphon rain gauge was well known to give underestimates for intensive rainfall.

(*b*) The maximum recorded rainfall in 1 hour in Hong Kong over a period of 70 years was 3·96 in. corresponding almost exactly to supply curve 4·0.

(*c*) In the southernmost parts of the United States, it was estimated that supply curve 3·25 corresponded to storms to be expected once in 10 years, and supply curve 4·0 to those to be expected once in 50 years. Similar figures were quoted by the D.S.I.R. Road Research Laboratory for Java.

REFERENCE

1. United States Army Manual, "Airfield Drainage".