

work from the quarries, the contractors had found great difficulty Mr. Gwyther. in getting enough stone to provide the coping on the top of the rubble pitching. He did not think one could count on being able to dress the Pulau Ubin granite. The stone was too brittle. There were places in the pitching where the stone had cracked, apparently due to variation in temperature. The high-water and low-water levels had been taken over 1 year. He had spent some time trying to solve the tidal problem, and he thought the only thing to do was to consider the two separate tidal waves, one on the east and one on the west, and regard the original tide as being the result of those two, one superposed on the other. Applied to the middle diagram of *Fig. 12*, he thought that would explain the difference in the high-water and low-water levels since the causeway has been constructed. The voids in the causeway were estimated to be 43 per cent. Some slight cracks had been found in that part of the lock-wall which occurred between the portions founded on piles and on red clay. Such hair cracks were found in most walls, where two lengths had been joined together, one having been built some time before the other, as was the case in this instance.

### Correspondence.

Mr. W. T. HALCROW congratulated the Author on his interesting Mr. Halcrow. description of an important engineering work. Reference was made on p. 268 to the presence of old timber on the site of the lock. For many years before the Johore Railway was constructed a saw-mill existed on the banks of the straits and adjoining creek. Timber was brought in native craft, and during the process of unloading, some of it was lost in the muddy foreshore and never recovered. Subsequently a sea-wall was constructed and land was reclaimed, on which the railway-station now stood. The north wall of the lock was situated entirely on the reclaimed land, and work was commenced on it in advance of the south wall, which came on the foreshore and required a coffer-dam for its whole length to allow of the work being carried out in the dry. The borings indicated clearly the nature of the strata and the existence of old timber, but neither its condition nor its quantity was realized until the ground was opened out. Except where in clay at the eastern end, the trenches for the north wall were designed to be of 6-inch timber sheet piling, front and back, and divided by cross piling into lengths of about 60 feet, alternate lengths of wall being built and the intervening spaces subsequently

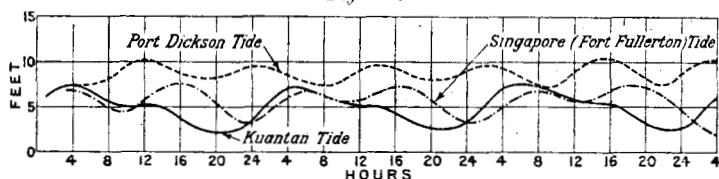
Mr. Halcrow. filled in. It was soon found to be impossible to drive the sheet piling, owing to the old timber, which lay at a depth of about 10 to 15 feet below the surface of the ground. A narrow trench was therefore excavated along the line of the piling down to the timber, which was cut out. The work was laborious, as the tide had free flow to the trench. The logs having all been cut through, the trench was filled with clay, through which the sheet piling was driven, making a satisfactory job, water troubles being of a minor nature. In the excavation of the wall trenches old timber was found in large quantities, there being many hardwood logs ranging from 18 to more than 30 inches in diameter. Similar difficulties were encountered in driving the piles of the coffer-dam, but fortunately only occasional logs were met with, and it proved to be possible to do the work without preliminary trenching. The only mishap was the one referred to in the Paper.

Mr. Mager. Mr. F. W. MAGER remarked that the railway between Kuala Lumpur, the chief town of the Federated Malay States, and Singapore was only opened for traffic about 15 years ago, and the east-coast extension as far as Kuala Lipis, the capital of Pahang, 8 years ago, while Bangkok had still more recently been linked with the system. That a work of the magnitude of the Johore causeway should so soon have become necessary was evidence of the remarkable development proceeding in the countries served by the Federated Malay States Railways. One link yet remained to be forged—that with the Burmese State Railways—before the Malayan railway system became connected with the Indian; but even that was now in sight. Those who, like Mr. Mager, had travelled on the night mail from Kuala Lumpur to Singapore and experienced the miseries attendant on crossing to Singapore island on the old passenger-ferry, or doing the return journey at 10 p.m., would appreciate the convenience to the passenger of the causeway, economic considerations quite apart. The carriage-road, also carried by the causeway, was of no less value than the railroad, since by it Singapore was now connected to the road system of Malaya; a system including 2,500 miles of fine carriage-roads in the Federated States alone, all built not only within the memory but within the working lives of men still living.

The conception of this structure was, he had been informed, due to the late Mr. W. E. Kenny, M. Inst. C.E., a former chief of the Public Works Department, under whom it had been Mr. Mager's privilege to serve. Like other great conceptions it was essentially simple, the one problem being how to deal, both in design and construction, with irregularities in water-level due to

tidal action and the currents resulting therefrom. The effect of the causeway on the tides had been closely studied. The point was one of interest, because Singapore was the meeting-place of two tidal systems of quite different characteristics. That ruling on the west coast of the peninsula was always marked by two high and two low waters each day, but that on the east coast by one high and one low water succeeded by a second high and low water of considerably diminished range, the difference between the heights of this inferior

Fig. 16.



tide sometimes disappearing altogether; while the tides at Singapore tended to show the features of the east coast, but in a less marked degree (*Fig. 16*). It seemed possible that the tides might now assume, on opposite sides of the causeway, the widely-differing characteristics of the west and east coasts respectively, rather than the intermediate features of the tides at Fort Fullerton. He regretted the omission of any particulars of cost and of the nature and organization of the labour-force employed, and he trusted that these details might eventually be supplied.

The AUTHOR, in reply to the Discussion and Correspondence, The Author. observed that several of the points raised had already been dealt with. With regard to the quality of the granite from the Pulau Ubin quarry, from his experience of this stone he did not consider it suitable for dressing, as it was brittle and full of irregular cleavage planes. There were, however, other quarries on that island from which, he believed, stone suitable for dressing could be obtained.

The information given in the Paper regarding the lowering of the level of L.W.S.S.T. on the eastern side of the causeway was derived from the tidal records taken for a year subsequent to the closing of the channel, and was assumed to be sufficiently accurate for all practical purposes. He was of the opinion that it would be reasonable to assume that the same conditions would obtain for some miles from the causeway, and agreed with Mr. Savile that they would have an important bearing on the cost of any works projected in that vicinity.

The height of the causeway above high-water level was ample to provide against wave-action, as the Strait was always calm. The

The Author. parapet on the sea side of the roadway was more of a traffic protection than a provision against possible wave-action.

The reasons for the procedure adopted by the contractors in the final closing of the channel had been fully explained by Sir Evan Jones and the Author would merely add that this method had resulted in the closing of the channel about 3 weeks in advance of the date on which it would have been closed by extending the pilot banks until they met; which was no inconsiderable saving of time, and in his opinion fully justified the method adopted.

In reply to Sir Brodie Henderson, the culverts had been provided to prevent the accumulation of floating refuse in the vicinity of the lock, and an interesting illustration of their action had been afforded during the construction of the works. While the culverts were under construction, their waterways were closed by temporary wooden dams to stop the strong rush of water through them at certain stages of the tides, which otherwise would have washed away the bed of crushed stone on which the invert blocks were set. These temporary dams were left in position during the completion of the temporary bank and until the culverts were completed to the full width of the causeway, by which time a considerable quantity of floating refuse of all descriptions, including sundry dead animals, had accumulated, especially on the western slope of the work. On the removal of the temporary dams the refuse gradually disappeared, leaving the slopes remarkably clean. Having regard to the offensive nature of such an accumulation of refuse as described above, the Author considered that the provision of the culverts was very necessary.

Although nothing in the nature of quarry refuse had been permitted to be used in the work, no limit had been specified to the smallness of the stone to be deposited in the main portion of the work; but actually nothing smaller than medium-sized spalls had been used.

He regretted that he was not at liberty to furnish particulars of costs. He might state, however, that the total cost of the work was about £2,000,000, which was borne by the Governments of the Federated Malay States, the State of Johore, the Straits Settlements, and the Singapore Municipality, in the proportions of approximately 72, 18½, 8, and 1½ per cent. respectively.