Correspondence.

Mr. James Brown was rather surprised to read the Author's statement that a cast-iron-lined tunnel would have cost 30 per cent. more than one lined with concrete. The late Mr. Edward Manisty, M. Inst. C.E., to whose report of October, 1906, reference was made on p. 169, after carefully studying the tunnel scheme along with the railway authorities in Buenos Aires, had advised the adoption of cast-iron-lined tunnels of 17 feet 3 inches internal diameter, and estimated their cost at £65 per lineal yard, or about £71 per metre. The actual average cost of the various cross sections of the goods tunnel, as constructed, came to £68 3*s.* 6*d.* per metre. Mr. Brown.

He did not know Mr. Manisty's reasons for recommending a tunnel of so small a diameter, as it would not admit the standard construction gauge of the railway company, as shown in *Fig. 8.* To do so would require a tunnel of minimum internal diameter 18 feet 8 inches, and the preliminary tenders the Author referred to were, Mr. Brown believed, for a tunnel 5·70 metres (18 feet $8\frac{1}{4}$ inches) in internal, and 6·04 metres (19 feet 10 inches) in external diameter. A tunnel of this diameter would of course cost more than the one proposed by Mr. Manisty, but the reasons he gave for his preference for a cast-iron-lined tunnel, namely, safety of buildings, rapidity of progress, facility of construction, fewer labourers required, less excavation and therefore less cartage of spoil, etc., were, Mr. Brown thought, quite sound. As to safety of property, it was true that the "tierra pampeana" in Buenos Aires was excellent material for tunnelling purposes; it was better than the London clay, which was very good, and the Author had described how the work was carried out under the works of the Anglo-Argentine Tramways, with very little cover and very little timbering; but there was a section between kilometre 4,400 and the western mouth of the tunnel where the ground was soft and rather wet, and the roof had to be poled, and eight (sometimes ten) bars 10 inches in diameter had to be used. All the poling boards, and occasionally some of the bars, had to be left in permanently, and here a cast-iron-lined tunnel driven with a shield would certainly have been advantageous. Altogether in the goods tunnel there were about 5,000 square metres of 1-inch thick timber (or, say, 4,500 cubic feet) left in over the concrete arch. As to speed

Mr. Brown

of construction, with a mechanical excavator shield, as used in London tubes, and a cast-iron lining, much better progress would have been possible. The average speed of all six faces during actual time of working was 44 metres per month, the highest face showing 60·5 metres, and the lowest (on the section mentioned above) 26·6 metres. This rate would easily have been doubled with a cast-iron tunnel. The greatest difficulty in the construction of the concrete tunnel was the placing of the concrete, particularly in the crown of the arch. The labour required per cubic metre of excavation was just over 9 man-hours, but 20 man-hours were required per cubic metre of concrete. Owing to the centering having to be left in position for several days, and to the necessity for keeping the excavation going on ahead simultaneously with the concreting of a length (the skips of spoil running through the length where concreting was in progress) the working space was very much restricted and there was no room for mechanical mixers. Even if they could have been used they would not have solved the difficulty of placing the concrete in the crown of the arch, which had to be done by hand and was a slow and unsatisfactory operation. It was difficult to get the concrete thoroughly rammed in the key, and grouting afterwards was absolutely essential. In a cast-iron-lined tunnel, not only would the operation of grouting be easier, but less grout would be required, while the erection of the lining was a much simpler and quicker process, no centering being required, and the working-space being therefore much greater. The cost of the centering alone in the concrete goods tunnel came to 3*s.* 1*d.* per cubic metre of concrete. As Mr. Manisty remarked, there was also less excavation for a cast-iron tunnel, and therefore less cartage of spoil, and this was an important consideration in a city like Buenos Aires, where the distance to an available spoil ground was long, and the streets were narrow and congested with traffic.

With regard to the waterproofing of the tunnel, the average area waterproofed per lineal metre of goods tunnel worked out to 3·85 square metres, and in a cast-iron-lined tunnel would have necessitated the caulking of some 10½ lineal metres of joint. This, he was sure, would have resulted in a more satisfactory job at less cost. That the results as regarded watertightness were not so good as had been hoped was due, he thought, to the soft bitumen sheeting becoming slightly perforated in places by the sharp edges or points of the granite used as aggregate in the concrete; and while the leakage was slight, he believed that with a cast-iron tunnel and caulked joints there would have been practically none. The principal reason why the cost of a cast-iron tunnel should be

so much higher than that of a concrete-lined one was, of course, the heavy freight, making the price of the cast-iron-lining delivered in Buenos Aires very high, but the same heavy freights had applied to the cement for the concrete tunnel, and the sand and stone had had to be brought from the State of Uruguay at a heavy cost, so that he thought another reason for the apparently greater cost of a cast-iron tunnel must be that it was compared with the low cost at which the concrete tunnel had been carried out. Mr Brown.

At first it was hoped that by allowing the air-compressors, when not required for grouting purposes, to blow into the working-faces, the air would be kept sufficiently pure, but the grouting took up too much of the time of the compressors, and the supply soon proved inadequate for efficient ventilation, especially while an attempt was being made to use the petrol locomotives in the tunnel. These machines—"New Century" petrol locomotives—while excellent for outdoor work, or where there was a copious air-supply, were found impossible in the tunnel, except at the open ends. They heated the atmosphere to an uncomfortable degree and practically used all the air in the tunnel, so that the men could not continue at work. He requisitioned five electric locomotives of 2-foot gauge for this work, but the contractors were persuaded to try the petrol locomotives, and when these were found unsatisfactory, they went back to the original requisition and sent out four electric locomotives, which accounted for the nine locomotives in the list of plant (p. 195). Five were used on the tunnel contract, and four went to another contract the firm had in hand in Buenos Aires.

It was a pity the Author had not given some particulars of the design or a cross section of the wall with its reinforced-concrete bearing piles. It would be of interest to many members of the Institution.

Mr. J. L. Busfield had noted with interest that the distribution of suburban traffic on the Buenos Aires Western Railway, as shown in *Fig. 5*, was much more uniform than was generally obtained in suburban traffic. There was the usual peak of incoming passengers between 8 and 9 a.m., and the greater peak of outgoing passengers between 6 and 7 p.m., amounting to about 10 per cent. of the whole traffic, but the percentage of passengers carried throughout the rest of the day remained fairly high. From Mr. Snyder's diagram showing the distribution of traffic in New York City,[1] it would be seen that a much larger peak load had to be handled, namely, Mr. Busfield.

[1] Minutes of Proceedings Inst. C.E., vol. cxciii, p. 205, *Fig.* 16.

Mr. Busfield. nearly 15 per cent., necessitating more extensive terminal facilities in order to deal with the same amount of traffic per diem; and the Author gave the corresponding figure for Liverpool Street, Great Eastern Railway, as 19 per cent. The Author explained that the territory served was not well developed as a suburban area, but retained the character of country villages. As the district became more developed in the form of residential suburbs—which would naturally follow improved terminal facilities in the city—the peak load of the traffic would tend to increase to the figure of London or New York, thus putting a greater tax on the terminal during certain hours of the day. The handling of traffic of this nature would eventually necessitate the running of trains into the terminal during the morning rush hour with great frequency, but only a limited number of these trains need take outgoing passengers on their return trip. To cope with this condition of traffic the alternatives would be either to store the trains beyond the station platform until they were required for the heavy outgoing traffic in the evening, or to return them to the coach-yard as expeditiously as possible, the majority of them not stopping to pick up outgoing passengers. In the plans that were being carried out, provision was made for two tracks beyond the interchange platforms, which could be used for storing two trains; but this would not appreciably relieve congestion when trains had to be run at 2-minute intervals. To provide more tracks at this point for storage purposes would not be economical, as extensive underground construction would be necessitated. In order to adopt the second alternative it was necessary to get the empty trains out of the terminal as expeditiously as possible without confusion with incoming trains, or with those outgoing trains which were to pick up passengers. A way in which this could be performed with the simplest train-movements was by the use of a third track situated between the incoming and outgoing main tracks, and suitably connected with cross-overs. Mr. Busfield would be interested to hear whether this plan had been considered, as it was not referred to by the Author. Possibly land or other restrictions not apparent in the drawings would render it impossible to use the wider station necessary to carry out a plan on such lines. He had been connected with a similar development being carried out by the Canadian Northern Railway at Montreal. In this case, in order that the centre of the city might be reached, a $3\frac{1}{4}$-mile double-track tunnel had been constructed, giving access to a low-level passenger terminus. It was proposed to continue the tracks on a viaduct over the low-level streets, reaching a large goods terminal in the centre of the wholesale district, and also connecting with the tracks of the Harbour Commission along the waterfront.

Mr. CHARLES S. CHURCHILL remarked that one of the points of special interest in the Paper was the careful record of the character of the material in which the greater part of the tunnel was built, described as being like a soft rock; strong enough to sustain adjacent buildings, and yet soft enough to be removed without blasting and by hand labour. The tunnel work therefore was somewhat special in character; the employment of mechanical devices for the removal of this material having been below the average of experience in tunnel construction in recent years. Another point of interest was the fact that the concreting was done by hand labour, without the use of mechanical mixers and other devices, indicating that men were easily obtainable, and at such low cost as to make the concrete work economical by hand labour, as well as the excavation of the tunnel itself. Inasmuch as these conditions were not often met with, it seemed important that the Author should also place on record the daily wages of labourers and the number of men employed in excavating the tunnel material and in concrete work. This information would be of special value because the progress in the construction of the tunnel was good and corresponded closely with the original estimates. Mr. Churchill.

The AUTHOR, replying to the Correspondence, agreed that a cast-iron lining would have had some advantage over the concrete-lined tunnel in certain places, but he did not consider that the difference of cost—which would have been considerably greater than the figures given by Mr. James Brown indicated—would have been justified. It was rather misleading to quote Mr. Manisty's estimate for a much smaller tunnel which would not admit the standard construction gauge established by Argentine Railway Law, especially as that estimate was made several years earlier than any of the others, when prices were considerably lower. When a decision was arrived at as to the type of lining, the Author had before him not only his own estimates but also the tenders of Messrs. C. H. Walker & Co., for whom Mr. Brown had acted as agent during the construction of the work. The estimates and tenders all referred to the type sections mentioned on p. 186. The amounts were, in round figures:— The Author.

	Per Lineal Metre.		
	Concrete Lining.	Cast-Iron Lining.	Difference.
	£	£	£
Author's Estimate	62	84	22
Contractors' Tender	63	104	41

The Author. That was, according to the tender of Mr. James Brown's principals, £416,000 for cast-iron lining, against £252,000 for the concrete lining, or a difference of £164,000, assuming in each case a length of 4,000 metres.

In reply to Mr. Busfield, the two tracks beyond the terminal station were not intended for storage purposes, but simply for shunting trains from one platform to the other without interruption of traffic. To provide storage sidings at this point would have been impossible, even if the cost of doing so had not been prohibitive. The storage yard was provided near Caballito, about 2 miles away on the main line, where sidings could be built on the level above ground, on land the greater part of which was already the property of the Railway Company.