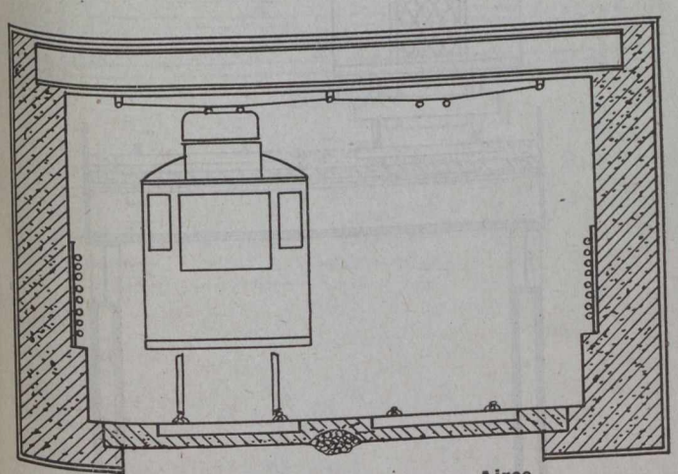
sand with outcrops of rock according to the district. The chief difficulty met with is in excavating through quicksand which, owing to the great weight of the surrounding buildings, persists in pouring up into the subway and necessitates the retaining walls being carried to a considerable depth below the floor of the tunnel. Underpinning of building foundations is another heavy item in the cost of construction. Subways are excavated by the cut and cover method, but civic ordinances usually require the street to be timbered and made safe for the ordinary traffic to proceed during excavation. This means that hand labor only can be used and mule trains will be necessary for bringing the muck away from the heading. Appropriation of cellars and the re-location of sewers, telephone and power cables is a necessary preliminary work which must be completed before construction proper is begun.

Figs. 1 and 2 show diagrams of typical steel-beam subways in Buenos Aires and Hamburg respectively. The former is part of the new rapid transit development of Buenos Aires and runs through the heart of the city from Plaza Mayo to Plaza Once, a distance of 2½ miles, the construction being now under way for a further 2½-mile



**Subway Construction, Buenos Aires.**

extension to Caballito, where the subway cars come up to the surface and continue the journey along the highway to the more remote suburbs. The line now in operation involved the excavation of 527,000 cubic yards in alluvial clay or "tosca" and the use of 98,000 cubic yards of brick masonry and 13,000 tons of steel. Brick masonry is used practically to the exclusion of concrete, probably because all the cement used has to be imported whilst the brick is a local product. The cost of construction on this line amounted to $2,680,000 per mile of double track.

The Hamburg subway, opened a few years ago, is part of a suburban system of which 3.41 miles is elevated 10 miles on the surface on private right-of-way and 4.15 miles underground. The construction is steel beam with steel bents in the centre of the tunnel and concrete retaining walls. Construction costs figured out at $1,000,000 per mile of double track and it is interesting to compare this extremely low cost with the figures prevailing in America of $2,250,000 to $3,000,000 per mile of double track.

Reinforced concrete for subway construction has been employed with success, notably in the Boston Boylston Street subway and in New York for the Hudson and Manhattan Railway.

The third type of construction is the deep level tube, which is preferable in some locations to the shallow subway. In London, England, where this line has been the furthest developed, the necessity of crossing under the River Thames as well as the existing underground railways and sewers was the main factor influencing the adoption of tubes. Added to this the presence of the blue clay belt from 40 to 200 feet below the street surface rendered it possible to mine by the use of a shield without blasting or any interference with the surface except at the shafts. The clay contains little rock or water-bearing strata; other locations are not so fortunate as London in this respect, however, and it is doubtful whether tubes could be driven through a subsoil like that of Toronto. In New York the deep level tube is economically impracticable except for river crossings on account of the rock and quicksand which would be encountered.

The depth at which the London tubes are driven, 60 to 200 feet below the street, is such as to cause no interference with foundations, and where necessary the railway cuts across a block instead of following the alignment of the street above. The method of shield construction forms a constant support to the soil above and little or no timbering is used. The shield consists of a steel cylinder about six feet long and the same diameter as the outside of the tunnel segments. The front of the shield forms a cutting edge and the back is provided with seven or eight hydraulic rams around the circumference. These rams obtain their purchase on the last tunnel segments bolted into place and drive the shield forward at the rate of about ten feet per day when working in clay. In the cover afforded by the shield the heading is driven and earth excavated by hand or by a compressed air excavator. Behind the shield as the work progresses the muck is run out along a tram line and the cast-iron tunnel segments are bolted into place. Afterwards the space outside the segments is filled with cement grout pumped through holes in the casting, thus protecting the segments from rust and decay by the elimination of air spaces.

The foregoing has briefly summarized the methods adopted in building railways of the three types.

**Table I.—Average Length of Run on City Rapid Transit Systems.**

| Railway. | Stops per mile. | Average run, feet. |
|---|---|---|
| Buenos Aires subway ..... | 3.10 | 1,690 |
| North Western Ry., London... | 1.20 | 4,400 |
| District Railway, London ..... | 1.50 | 3,500 |
| Inner Circle, London ..... | 2.10 | 2,510 |
| Central London, London ..... | 2.10 | 2,510 |
| South London Elevated ..... | 1.20 | 4,400 |
| Interboro' Subway, New York. | 2.40 | 2,200 |
| Berlin Elevated ..... | 2.00 | 2,640 |
| Hamburg Elevated ..... | 1.90 | 2,780 |
| Average ..... | 1.95 | 2,700 |

Summarizing the costs, the investment per mile of double track for construction alone is:—

| | |
|---|---|
| Elevated railway ..... | $ 632,500 |
| Subway ..... | 2,500,000 |
| Tube ..... | 2,550,000 |

The above figures are purely construction costs; that is, they are quite independent of the traffic. The railway will cost just as much to build whether one or one thousand trains run over the mile of double track in a day. We have now to estimate and add to the above amounts the cost of the equipment of the road; that is, the cars, feeders, substations, shops and other items