duration, and supplemented with practical training in an office, whether it be professional or commercial. The essential thing in that course is that the industry or profession has told the college what they want, and the college does not do any dictating in the form of the course. The university has designed its course in its own way and seeks recognition of that, from the profession, and if the profession do not like it they do not give it recognition.

We are also beneficiary of the Registration Act. Nobody can qualify and practise as a quantity surveyor unless he is registered. This licence costs money, and is renewable each year. There is no further form of examination for this particular licence and it can be withdrawn for inefficient practice. Secondly, the membership of the Association is only at one level, it does not have fellows, we are either members or not, but within that structure there are two types of members. Salaried members, who pay a very low fee, and the practising boys who pay an enormous fee. The Registration Act is there to protect the public, and for the benefit of quantity surveyors.

Lastly, I would like to say that we as an Association do not conduct the examinations except for a professional competency test for people who have cognate or somewhat similar qualifications to enable them to understand Roman Dutch law, which is different to the law which you have in the United Kingdom.

We do not have a society for technicians, they tend to find their home in construction companies, or professional offices, but there is a move to set up an organisation to look after them within the association. We do not wish to see two separate bodies because we would prefer them under one roof rather than two.

(*At this point the conference adjourned for lunch. Part Two of this report, giving the proceedings of the afternoon session, will appear in the next issue.*)

Tunnelling methods in the Hong Kong MTR

During their visit to Hong Kong for the Inauguration of the Institute's new Branch the President and the Secretary were fortunate enough to be shown many sites on the Mass Transit Railway and to meet members employed on this vast and fascinating project. The following article on tunnelling methods is reprinted by kind permission of the Mass Transit Railway Corporation.

The north Kowloon section of the Hong Kong Mass Transit Railway Modified Initial System (MIS) runs from Boundary St to Kowloon Bay and includes the line from Choi Hung to Shek Kip Mei which opens in September, 1979 – the first section of the 15.6 km railway to become operational. The full US$1 261 million MIS becomes operational in March, 1980.

Types of construction on the Boundary St-Kowloon section vary considerably due to the topography of the ground and the Corporation's requirements.

Principal forms of construction are elevated rail track, including three stations at high level, cut and cover with a RC box section in which the tracks run, and the remainder in tunnel.

Station construction also varies but all are based on some form of open cut method apart from the elevated section. In addition, two of the open cut stations include sections of bored tunnel.

Following is a review of the sections which employ bored tunnels to house the running tracks.

The mode of construction differs to suit the prevailing ground conditions together with the fact that the contractors have opportunity to nominate their own form of construction due to the contracts being on a "design and construct" basis. This situation has not induced high mechanised or sophisticated tunnelling techniques from either the local or international contractors as may have been envisaged. Such a situation is the product of the stations being at short intervals, this being a function of the system which is peculiar to Hong Kong's specific needs, compared with similar railway networks elsewhere in the world. Most tunnel drives are, therefore, confined to 500 m-700 m in length and, for economical reasons, is not conducive to mechanisation to any major extent.

Section 1 (Contract 202) from Boundary St to Shek Kip Mei is handled by Maeda Construction Co., Ltd. of Japan.

The first 200 m of this section is constructed by cut-and-cover with the initial length employing packed-in-place bored piles. The running tunnels over this length are in a RC box which is divided horizontally in the centre to facilitate the down track running tunnel immediately above the up track.

On reaching the Police Recreation Ground in Sai Yeung Choi St the two tracks begin to divide with the up track commencing on a downward gradient for its approach to Shek Kip Mei Station where both tracks are level.

At this point in Sai Yeung Choi St, the open cut excavation has been formed within a sheet piled cofferdam, the final cut-off being achieved with the aid of ground treatment. Here the cut and cover construction gives way to tunnelling and the two portals lie at the north end of the cofferdam.

The ground condition in this section consists of saturated, completely decomposed granite with occasional boulders, varying greatly in size. Originally it was

intended to employ compressed air on this section which would have balanced the water pressure and provided a stable ground condition suitable for tunnelling. However, the contractor decided that as such poor conditions were only likely to exist for some 80 m-90 m, the use of such a method was uneconomical and they chose to adopt the "Side Heading Method" to construct the 4900 m dia tunnel.

This method consists of driving two side headings, 1.75 m x 3.0 m high, on each side of the tunnel at invert level, using steel frames at one metre centre and forepoling with steel laggings between to support the ground. To assist the latter, local "well-point" dewatering was employed from within the headings together with some ground treatment.

These headings were driven until the ground gave way to a more competent material at which point full face tunnelling was employed. On completion of the headings the lower section of the permanent concrete side wall was poured, working back towards the portals.

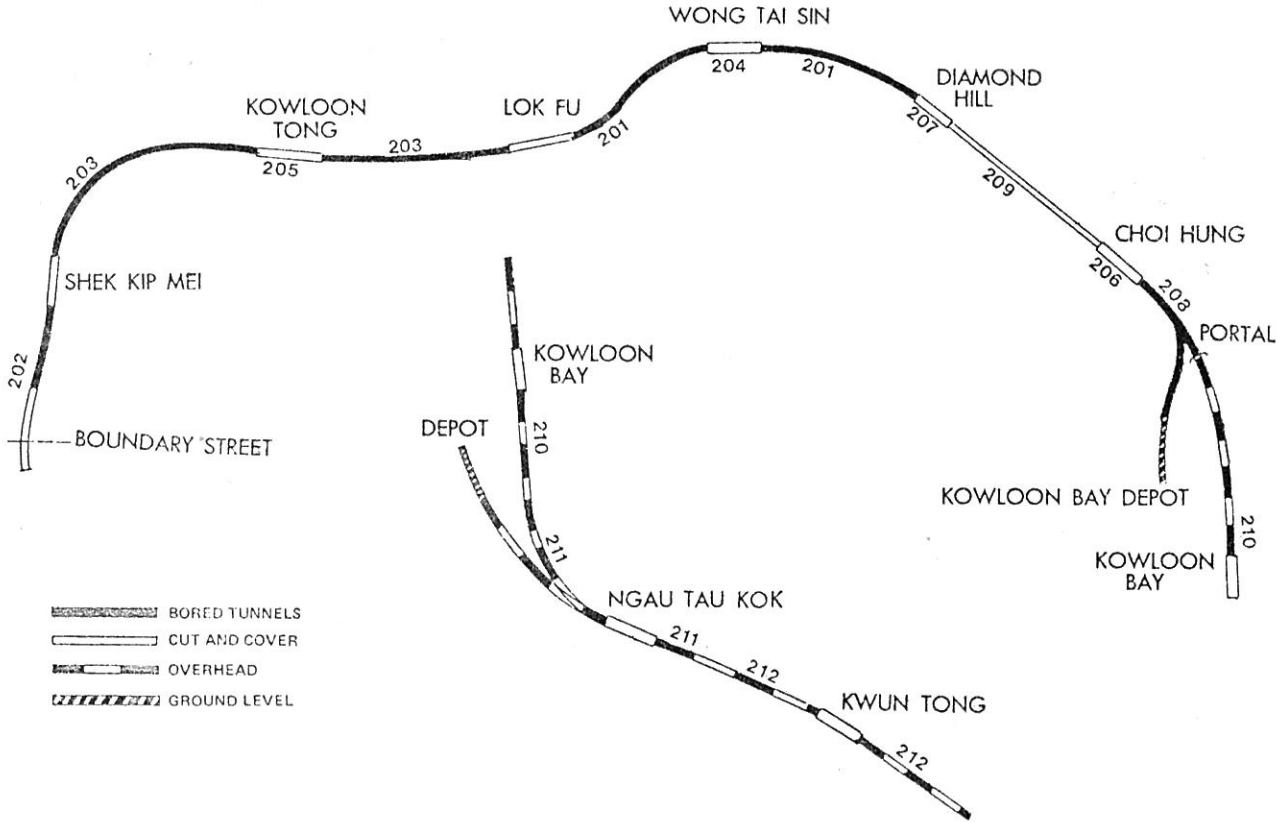
When this operation was completed, a ring cut commenced which entailed excavating for the crown (upper part) of the tunnel and supporting the ground by steel arches and laggings.

During this operation the tops of the lower walls were exposed. This was then followed by placing of the *in-situ* concrete lining forming the soffit, thus completing the lining for the tunnel with the exception of the invert or track slab. The latter being possible to complete after the removal of the dumpling of unexcavated material between the original side headings. However, invert concreting tends to be left until the tunnel drive is complete when it is done as one continuous operation.

After completion of this more difficult section, full face tunnelling began in ground varying between highly decomposed granite to fresh granite.

Conventional methods using hand-held pneumatic drills and air-operated pusher legs were applied with the aid of explosives. However, all ground had to be supported temporarily with steel arches and laggings, centres of supports being permitted to vary in spacing to suit ground conditions as encountered.

These drives continued toward Shek Kip Mei Station which is part open cut and part bored tunnel of 7600 mm dia. Also to be constructed to the south of the station are two tapered tunnel junctions, each of which reaches a maximum diameter of 10,800 mm at axis. The junctions permit trains to transfer from the up track to the down track or vice versa as required.



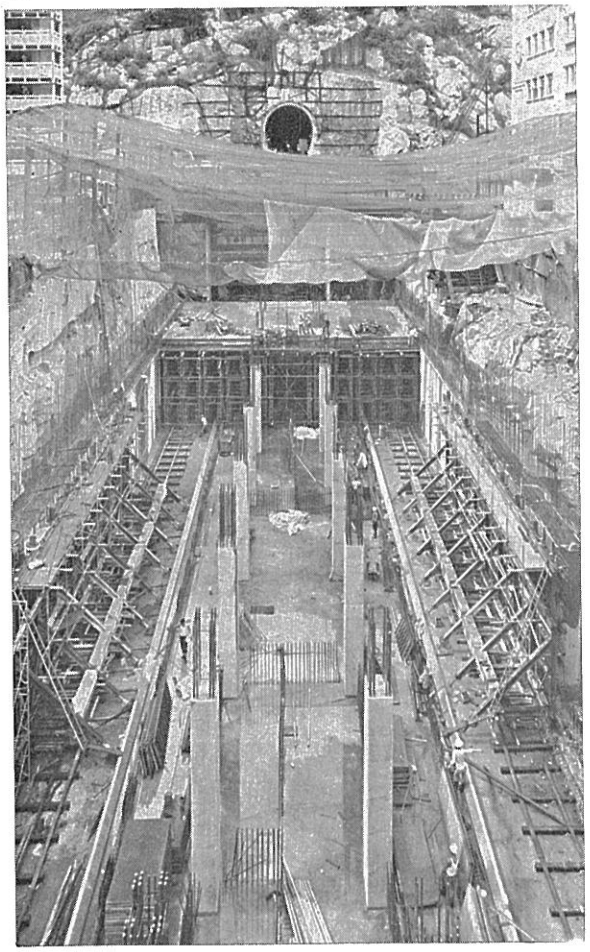
The actual excavated material during tunnelling operations is loaded by pneumatic loading shovels. These amount to a front end shovel loader which is mounted on rail tracks and throws the spoil back over itself onto an integral hopper and conveyor which in turn discharges into mine cars each of which is capable to load 4.5 m^3 of material and is hauled back to the hoisting location by battery operated locomotives. A temporary railway network has to be laid as the tunnels progress in order to convey material to and from the tunnel face.

The station tunnels are constructed in a similar manner except due to their increased cross-sectional area excavation is carried out in two parts, a top heading first and then the removal of the lower benching.

Section 2 (Contract 203) awarded to Kumagai Gumi Co. Ltd of Japan, consists of some 3587 m of twin running tunnels from Shek Kip Mei to Kowloon Tong and then on to Lok Fu, all of which are 4900 mm dia at axis having a horse-shoe profile.

Again the ground condition in these drives varied considerably ranging through all stages of granite from completely decomposed to fresh together with encountering alluvial deposits.

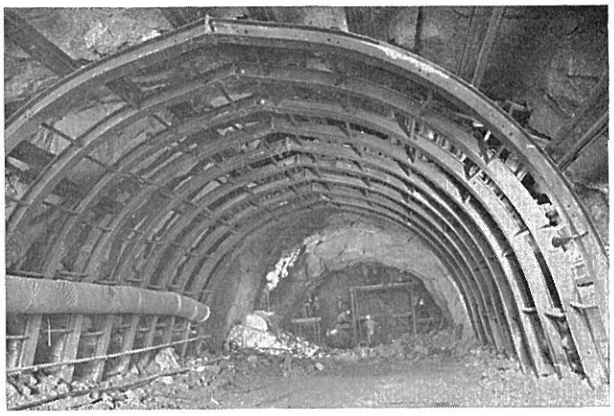
The drives between Shek Kip Mei and Kowloon Tong proved to be highly successful and despite encountering completely decomposed granite, neither compressed air nor ground treatment proved necessary as expected for the material was comparatively dry and stable. Good rates of progress were achieved often exceeding 30 m/week and the tunnels are now some 83% excavated and 53% *in-situ* lined.



View of Shek Kip Mei station from temporary deck looking south. Track slab and lower columns can be seen and formwork for side walls. Concourse slab first section in background

Most of the tunnel was advanced using traditional drilling and blasting methods similar to that described previously.

The section approaching Kowloon Tong Station, however, is in completely decomposed granite, together with colluvium and in general the ground cover above the tunnel is shallow; this section also passed beneath the Kowloon-Canton railway. In this case the contractor has decided upon the use of deep wells in this section in order to dewater the ground to ensure safe working condition. This will then permit the tunnels to be excavated and lined with *in-situ* concrete as for the previous sections.



Tunnelling (Shek Kip Mei to Boundary Street)

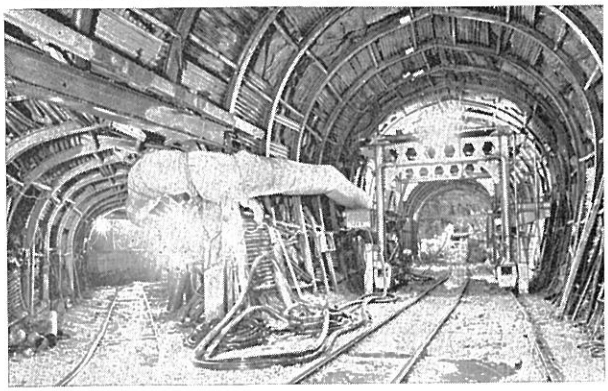
Tunnel drives between Kowloon Tong and Lok Fu basically fell into two different categories, one section being in saturated decomposed granite requiring the use of compressed air up to 1.2 bars, while the remainder tended to be in competent rock requiring the minimum of temporary support.

The contractor endeavoured to mechanise the operation in this section by employing roadheader machines. These comprise a rotary cutting head on a telescopic boom, the whole being mounted on a tracked undercarriage. As the cutting head bites into the face the spoil drops on to a front apron where a pair of oscillating arms gather the material and push it on to a chain conveyor which then feeds the spoil to rail-mounted mine cars behind.

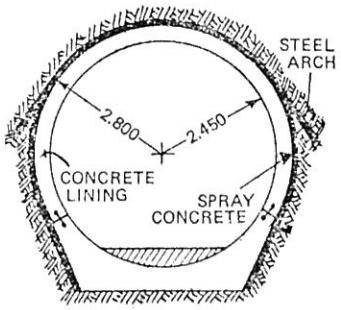
These machines proved successful in both the highly and completely decomposed granite under compressed air working. However, alluvium was encountered in the crown of the tunnel which required hand mining to ensure safe working and thus these machines were no longer used. The more traditional method of arches and forepoling was once more necessary.

In this section, ground treatment from the surface was necessary in order to stabilise the poor ground conditions above the tunnel in order to minimise settlement.

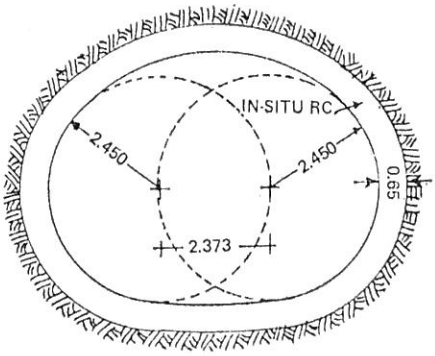
Section 3 (Contract 201) awarded to Metro Joint



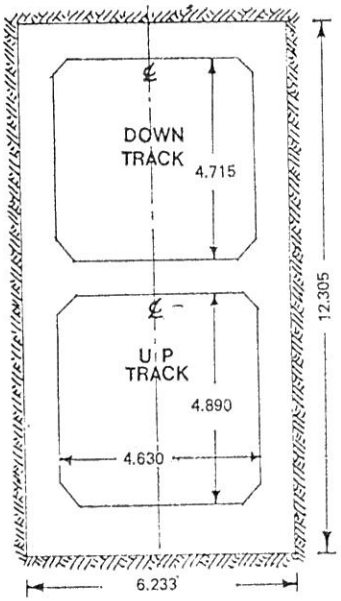
Shek Kip Mei to Kowloon Tong tunnels, with tunnel driving in progress



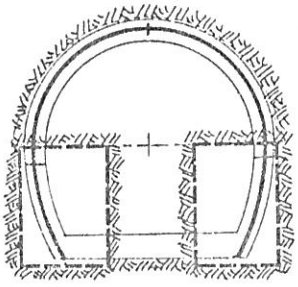
NEW AUSTRIAN TUNNELLING METHOD (201)



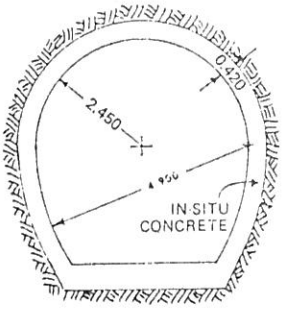
TAPERED JUNCTION (201)



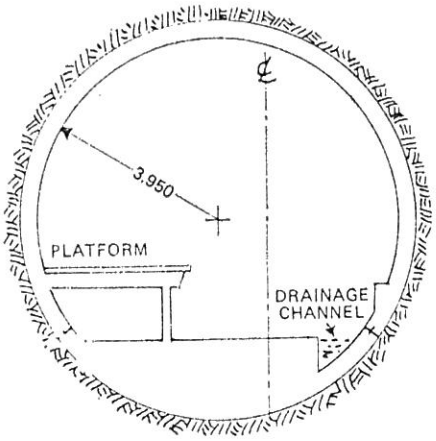
CUT AND COVER TUNNEL (202)



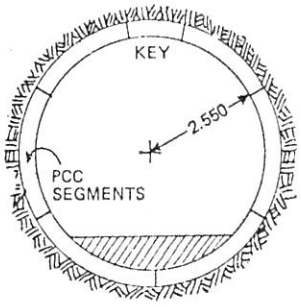
HORSESHOE TUNNEL (202) SHOWING SIDE HEADINGS



HORSESHOE TUNNEL (203)



STATION TUNNEL (201)



SEGMENTAL TUNNEL (201)

Venture is to construct Lok Fu Station which included some 90 m of bored tunnel of 7600 mm dia together with enlargement of 9600 mm dia and an ellipical ventilation shaft, 44 m deep, on the west end. The remaining 130 m of the station being formed in open cut.

Combined with this are two sections of tunnel, one between Lok Fu and Wong Tai Sin Stations and the other between Wong Tai Sin and Diamond Hill Stations. The former being a shield driven tunnel under compressed air, through fill material, completely decomposed granite and colluvium, with precast concrete segmental lining being employed. The latter section passes through ground conditions varying from fresh granite to completely decomposed granite and for this the "New Austrian Tunnelling Method" together with ground water lowering was decided upon by the contractor.

The shield in use tends to be sophisticated and was developed and manufactured by "Bade" of Germany.

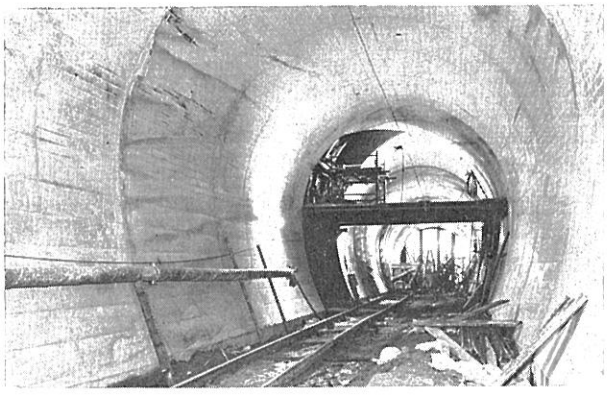
The basic concept of the shield is little different from those first developed in the 19th century, and consists of a cylindrical steel drum suitably strengthened with bulkheads etc, to withstand ground pressures.

Around the internal periphery are 12 pairs of hydraulic rams each able to provide up to 160 tonne force. These, in fact, thrust off the precast segmental lining which is built within the tail (or rear) of the shield and provides both the means of propulsion and steering in all directions. This constitutes the actual shield and its true purpose is to afford protection to the miners and normally enables safe but rapid excavation of the tunnel face in soft ground conditions.

Within this particular shield is housed an excavator arm which is similar to those of any hydraulic back-hoe machine commonly seen on any of today's construction sites. However, the arm has a greater number of movements in order that its open ended bucket can excavate anywhere in the tunnel face.

In addition the bucket can be interchanged with an impact hammer which permits rock or other hard obstructions encountered to be removed.

All the excavated material falls on to an apron and mechanical arms scoop the spoil on to a chain conveyor



Shek Kip Mei to Kowloon Tong up track tunnel, looking into Shek Kip Mei Station. Ventilation cross passage is seen on the left hand side. This cross passage will eventually house the impulse fans which will supplement the natural ventilation in the tunnel, caused by the movement of trains.

Up track tunnel from Lok Fu to Wong Tai Sin which has been driven under compressed air conditions

which in turn loads mine cars in readiness for its journey to the surface.

The precast concrete segments are manufactured on site by the contractor to very accurate tolerances, each weighing 2.25 tonne. Six segments together with a tapered key form a complete ring of lining 5100 mm in dia, being 1 m wide x 320 mm deep.

The segments are transported to the shield by rail cars and hoisted on to a conveyor by a small crane. At the end of the conveyor lies a hydraulic traversing table which places the segments on to an erector which then places them in the correct location. At this point the segments are bolted together manually and checked to see that they are in true alignment and position.

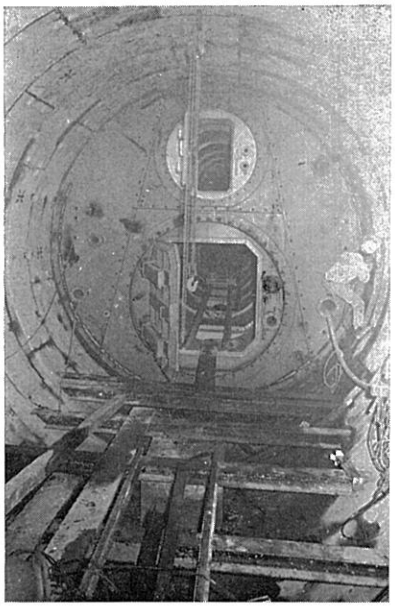
After the next length of tunnel has been excavated and the shield has shoved forward off the last ring built, sand/cement grout is injected under pressure through preformed holes to fill the annular void which exists behind the lining. On the completion of this operation, the final tunnel ring stands ready for inspection.

The conveyors together with power packs, hydraulic pumps, oil reservoirs, electric cable drums and motors, etc., are mounted on a series of trailers which run on rails on either side of the tunnel. This system of trailers extends for some 40 m, the whole being hauled by the shield.

In order to maintain the shield on its course, a laser beam is employed to provide a light source and is accurately located for alignment and graded by surveyors. The light beam can then be seen on present target screens, placed within the shield which are graduated and enable the exact position of the shields to be known together with it being possible to compute a projected location for the shield if it continued on that path. Thus the necessary steering instructions may be established by the supervisors in order that the shield driver can position his machine correctly.

Section 4 of the tunnels between Wong Tai Sin and Diamond Hill Stations were constructed using the New Austrian Tunnelling Method combined with ground water lowering.

This consists firstly of sinking a system of deep wells, along the tunnel route in which pumps are placed so that the water level is drawn down below the tunnel invert level. Such a method is an alternative to the use of compressed air working and removes the water rather than balancing the ground water pressure. This permits greater freedom of access but needs great care in



The low level siding tunnel between Chater and Admiralty Stations. Note the precast concrete lining. Installation of the bulkhead in progress with the man and material locks behind

installation and operation in order to maintain control and minimise settlement at ground level.

The New Austrian Tunnelling Method is an advancement on traditional rock tunnelling techniques. Normal drilling and blasting methods are employed to win the advance and immediately the rock face is exposed, a thin layer of spray concrete is applied to form a shell. This in effect provides an efficient seal to the surface of the ground from both water and air and does not permit the ground to relax and thus cause a major redistribution of stress, likely to induce a collapse. Then the steel mesh, rock bolts and steel arches are installed to reinforce the temporary shell previously placed. Further layers of spray concrete are then added varying in total thickness from 100 mm-200 mm depending upon the prevailing conditions.

Initial application of spray concrete not only provides stability to the excavated tunnel section but affords immediate protection for the tunnel workers.

Due to the overall size of the excavation, the tunnel has been advanced for most part by firstly excavating a top head followed by the removal of the lower benching. This not only minimises the surface area excavated at any one time but provides a ready-made working platform for workers.

In this situation a temporary narrow gauge railway is not employed to service the tunnel but rather lorries, dump trucks and rubber tyred or tracked excavator/loaders. Obviously an adequate ventilation system has to be employed to prevent the build up of diesel exhaust fumes.

On completion of the excavation of the tunnel a reinforced *in-situ* concrete lining is cast.

This section also included the construction of two large taper junctions having a maximum finished internal diameter of 10,400 mm and similar methods have been employed suitably modified to meet the requirements. These junctions together with other ancillary works will permit the construction of the East Kowloon extension of the Mass Transit Railway in the future without interfering with the operation of the existing route.

Section 5 (Contracts 207, 209 and 206) awarded to Paul Y Construction Co., Ltd, covers the construction of Diamond Hill Station, running tunnels and Choi Hung Station. The running tunnels between these two stations are being formed by cut-and-cover methods with an *in-situ* RC box constructed within.

Section 6 (Contract 208) also awarded to Paul Y Construction Co., Ltd, consists of two sections of work namely two single-track running tunnels from Choi Hung to the South Portal, at which point the track will be elevated above the Kwun Tong Rd, and the second being the departure and reception tracks to the Depot at Kowloon Bay.

This last section involves two single track tunnels from Choi Hung which merge into one twin track tunnel containing a cross-over. The tracks continue through an *in-situ* RC box section built by cut and cover method in 1975 during the course of the Kwun Tong Rd reconstruction, under a separate contract. From this point the tracks emerge into the open and climb up to the Depot at the natural ground level.

The tunnels for most part were driven through fresh granite with occasional veins of completely decomposed granite, using conventional drilling and blasting methods and again employing steel arches and laggings for temporary support. The permanent lining to the section is formed in *in-situ* concrete. However, for the first 80 m of three of the four tunnels, poor, completely decomposed granite was encountered which required the use of segmental, bolted cast iron lining similar to that used on London Underground Railway in UK.

Generally all the tunnel contracts are progressing well and several already near completion, well ahead of schedule. Some 75% of the tunnelling between Boundary St and Kowloon Bay is complete, over 50% of which is lined. Likewise, station construction is also advancing satisfactorily and all will be ready for its opening in autumn, 1979.

"I wonder if Chinese excavations start at the bottom".