International Hotline

Singapore's subway system

Keiji ORIHARA
Singapore Office, Kiso-Jiban Consultants Co., Ltd.

I have been involved in the construction of Singapore's subway system as a geotechnical engineer from the time when government approval was obtained in 1982 for the North-South and East-West lines, which were Singapore's first subway projects, until the Circle Line, which is currently under construction. I have served in a variety of roles, including the Owner's consultant, ground survey and measurement contractor, construction contractor's consultant, and designer for temporary works. I will give a brief introduction of Singapore's subway system and discuss the issues I have encountered in routine operations, along with my own impressions.

<u>Overview of Singapore's subway system</u>

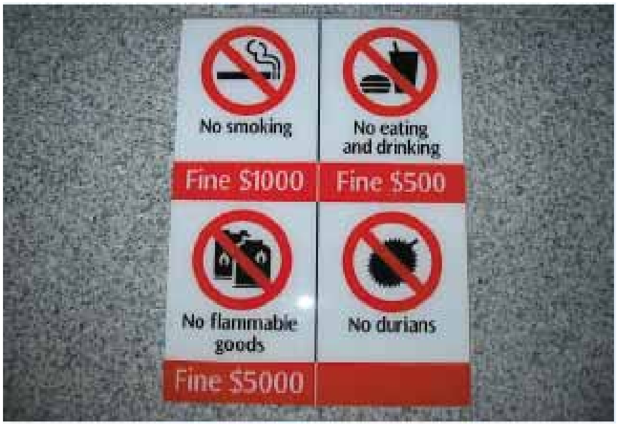
As shown in Fig. 1, the North-South Line, East-West Line, Changi Airport Line, and North-East Line of Singapore's subway system are currently in operation with a total length of about 120 kilometers. There are a total of 65 stations, and all lines are double-track. The subway runs underground in the urban district and is elevated in the suburbs, so there are no grade crossings with roads. When planning of the subway first began, some contended that a subway was unnecessary for a city which had a population of just 3 million persons (currently about 4 million). However, the subway is now used by more than 1.3 million riders each day, and it has become an indispensable means of transportation for the people of Singapore.

The following are some of the differences between Singapore's and Japan's subway systems. In Singapore, the platforms are separated from the tracks by walls with platform doors (Photograph 1). Subway stations are constructed to function as evacuation shelters. Eating and drinking in the subway are prohibited, and durians may not be carried onto the subway. And because Singapore has four official languages, announcements over the subway's public address system are extremely long.

Fig. 1. Map of Singapore's subway system, taken from the website of LTA.
(Red: North-South Line. Green: East-West Line. Purple: North-East Line.)

The main purpose of the platform doors is to allow more efficient air conditioning of the underground stations, and the above-ground stations do not have these partitions. However, they also help to prevent accidental falls. In the stations which function as evacuation shelters, the underground walls and ceiling slabs are two meters thick, designed to prevent the floor from caving in even if the columns should be suddenly broken by a shock. As you may know, durians are called the "king of fruit" in Southeast Asia, but they have a powerful smell which can persist for several days in a closed space, and this is the reason for the prohibition on carrying them onto the subway. Singapore is famous for its many fines, and as shown in Photograph 2, there is a fine of $500 (about ¥35,000) for eating, drinking, or carrying durians on the subway. The fine for carrying flammable substances onto the subway is ten times that amount.

Photograph 1. Platform doors.



Photograph 2. Items prohibited in the subways, with fines.

According to the magazine issued by the Land Transport Authority (LTA), the North-East Line, which was opened last year, is the first completely automated, unmanned subway in Asia.

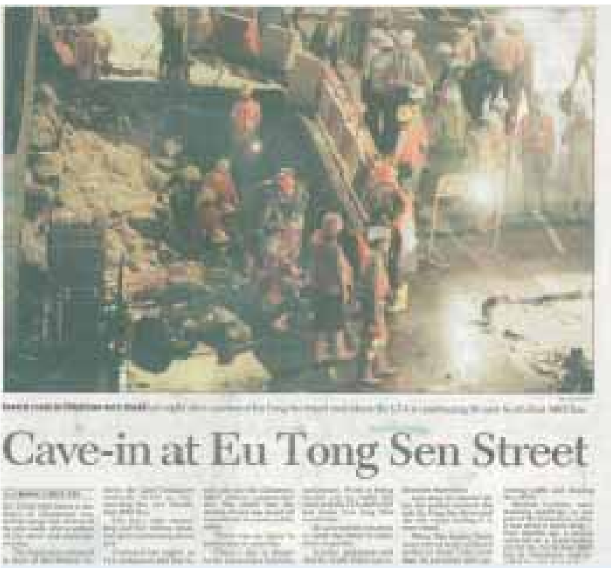
Risk assessment

The deepest subway station in Singapore is Dhobi Ghaut Station on Orchard Road, where the North-South Line intersects with the North-East Line. The platform is at a depth of five stories underground. During its construction, excavation was performed at a depth of 30 meters, next to an existing station and tunnel on the North-South Line. The allowable displacement of the existing station and tunnel was set at less than 15 millimeters, so the sheathing method and excavation method were studied with FEM analysis. The structures, ground, and construction processes were modeled using computer simulations; deformation of the surrounding ground and existing structures was predicted; control criteria for use during construction work were determined; and countermeasure work was proposed for each level of the control values. In subway construction in Singapore, this is known as geotechnical engineering risk assessment. The consultant for the construction contractor, who is accountable for execution of the construction work, performs this assessment and establishes control values for each of the monitoring devices to be used during construction work. The consultant must propose countermeasures to be taken when each control value is exceeded, such as closer monitoring if tunnel displacement exceeds Level 1 of the control criteria; revising the excavation process if Level 2 is exceeded; and halting excavation and adding braces if Level 3 is exceeded.

Drawing on past experience

Even with risk assessment, it is not easy to completely prevent all accidents. The ground in Singapore is highly varied with a complex intermingling of hard rock, soft rock, and weak strata. This has made all of the past and ongoing tunnel and station construction projects more or less difficult, and there have been accidents such as road cave-ins, collapsed sheathing, and deformation or damage to adjacent structures. Photograph 3 shows a newspaper article announcing a road cave-in which occurred during construction on the North-East Line.

This experience has been discussed in presentations and papers given at academic meetings and seminars which are frequently held in Singapore.


Cave-in at Eu Tong Sen Street

Photograph 3. Newspaper article announcing a road cave-in.

Engineers of LTA, the Owner of subway construction work, have recently published a paper which summarizes the construction work on tunnels for the North-East Line of the subway and gives details on the types of accidents which occurred in each section. Unremitting effort is needed on the part of both construction contractors and designers. The important thing is to make use of this past experience in the next subway construction project. For example, sheathing walls that combine sheet piles and soldier piles were heavily used in the North-East Line, but were not effective in reducing subsidence of the surrounding ground; and therefore, their use is prohibited under the particular specifications for the Circle Line. The Owner has shown a clear inclination to introduce new technologies and make use of past experience.

Implementation

In general, Singapore's subway construction projects have been ordered in the format of design and construction by a contractor. The contractor's design must be checked and approved by engineers of LTA, the Owner. The design criteria are determined by the particular specifications of the construction project and by British standards, so one might assume that engineers who are familiar with these standards could move ahead smoothly with developing the design and obtaining the Owner's approval. In fact, it isn't that simple. The design criteria do not prescribe all of the details of the design, and a great deal of interpretation is possible. Countless disputes and clashes of opinion arise, because the engineers of the management side and the contractor side come from different countries and have different technical backgrounds and differing experiences.

For example, the British standards allow the use of either total stress analysis or effective stress analysis for the lateral pressure for use in designing a temporary sheathing wall in a soft clay stratum. Japanese engineers are familiar with the total stress method and prefer it, but many of the LTA engineers are graduates of British schools and feel that the effective stress method, distinguishing between soil and water, is correct. Each side tends to argue from its own experience. Therefore, the process of submitting design documents, checking and comments, discussion, corrections, and resubmission is repeated an enormous number of times until the builder finally approves the design. There is a back-and-forth debate as the contractor proposes inexpensive methods to control costs, while the builder seeks to maximize safety.

Construction of Singapore's subway system began less than 20 years ago, with young engineers and a great deal of trial and error. An important lesson that I have learned through this process is that negotiations become much easier after trust is established by demonstrating a serious attitude to resolving problems and sufficient technical strength in order to earn the other side's trust. English conversational ability is also important, but I find this to be a secondary factor.

Future subway plans

The subway continues to grow in importance year by year, alleviating road traffic congestion and providing a convenient means of transportation. Stations rather than roads are becoming the focal points of urban development, as in Japan. Construction is now underway on the Circle Line, which will be completely underground with a total length of 34 kilometers. The blueprints for another three new subway lines have also been announced. The government of Singapore has indicated that it will order projects for one new subway or light rail (LRT) line per year. As subway construction continues, there will be a further increase in multilevel intersections with existing structures, leading to increasingly complex and advanced construction work and creating a need for more sophisticated design and analysis technologies, construction technologies, and risk management capabilities. Japan's experience with advanced civil engineering technologies can be a useful tool for participation in the construction of Singapore's subway system. Of course, a thorough understanding of the local situation is another basic prerequisite.