GESC's ROLE IN THE DESIGN AND CONSTRUCTION OF TRTS

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Abstract

Geotechnical engineering plays a critical role in the implementation of the Taipei Rapid Transit Systems (TRTS) project. The Department of Rapid Transit Systems (DORTS) of the Taipei Municipal Government has commissioned Moh and Associates, Inc. as the Geotechnical Engineering Specialty Consultant (GESC) to advise and assist DORTS on matters of geotechnical concern. This paper describes the functions and contributions of GESC on the TRTS project.

台北捷運中之大地工程專業顧問

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摘 要

大地工程對台北捷運扮演一個關鍵性的角色。台北市政捷運工程局委託亞新工程顧問公司擔任大地工程專業顧問以協助捷運局處理有關大地工程的事務，本文說明大地工程專業顧問之職能以及對台北捷運之貢獻。

I. Introduction

The role of geotechnical engineering in the design and construction of the Taipei Rapid Transit Systems (TRTS) cannot be over-emphasized. Sections of the network, whether at-grade or underground, require the expertise of geotechnical engineers. Joint development buildings, depots, elevated tracks and other viaduct structures of the TRTS are generally supported by deep foundations. Cut-and-cover stations, pedestrian malls, bored tunnels, daylight structures and other underground facilities directly interact with the surrounding soils of which the nature and characteristics can at most be only inferred from limited soil investigation data. With such a large scale of work, every aspect of design and construction becomes critical and the project cannot be realized with only mediocre efforts.

Previous local geotechnical experience may not be sufficient to successfully carry out the TRTS project. More extensive soil investigations have to be carried out, certain specialized field and laboratory tests have to be conducted, technology transfer through the collaboration of international technical consultants have to be resorted to, further researches on local soil behavior have to be made, more comprehensive back-analyses of previous construction projects have to be conducted, and so on. In light of these objectives and the ultimate goal of constructing the network in due time, the Department of Rapid Transit Systems of the Taipei Municipal Government (DORTS) has commissioned the Geotechnical Engineering Specialty Consultant (GESC) to handle all matters of geotechnical concern for the TRTS.

Planning and execution of the priority network of the TRTS is being done in three phases: Phase 1 includes the Mucha and Tamhsui Lines; Phase 2 covers the Hsintien and Nankang Lines; and Phase 3 includes the Chungho and Panchiao Lines which recently have been extended to cover the Tucheng and Neihu Lines. During the course of design, certain important geotechnical considerations have evolved due to problems inherent in the proposed works such as constructibility in relatively unclear ground conditions.

Phase 1 involves mostly above-ground structures except for a short section of excavation along the Tamhsui Line. Geotechnical concerns have mostly focused on pile foundations and earthquake design considerations.

In Phase 2, where the TRTS facilities have been generally designed as underground structures, the problem of building protection has been realized and different ground improvement and grouting techniques applicable to local soils have been further studied. In the eastern section of the Nankang Line where the subsoil is composed of very soft thick clayey deposits and where there is only very limited past construction experience, designs have necessitated the use of grout slabs below the excavation base, a technique which has never been used before elsewhere in Taiwan. In the Hsintien

Line where most areas are underlain by relatively shallow Chingmei gravels, the necessity of pumping from the Chingmei Formation during construction has led to a more detailed investigation of the groundwater condition as well as ground subsidence in the Taipei Basin.

Geotechnical problems continued to challenge the fate of the TRTS project as the design ushered on to Phase 3. Additional soil investigations have revealed that flammable methane gas exists at different locations of the Taipei Basin. Such presence of gas poses potential hazards during the construction and operation of tunnels so that necessary provisions have to be incorporated in the TRTS design. Aside from the immense building protection problem in Phase 3, geotechnical engineering design and construction have been confronted with the challenging task of tunnelling and constructing a crosspassage across the Hsintien river, excavation of about 36 m for a ventshaft in the Panchiao Line which is about the deepest excavation to be carried out in Taiwan, the technical design of large diameter station platform tunnels in stacked position using the NATM construction technique, and many others.

This section has emphasized the importance of geotechnical engineering in the TRTS project and has highlighted some major geotechnical problems and considerations in the design and construction. The geotechnical works involved are so immense. It can go without saying that the GESC's task and responsibility in the execution of the project are indeed enormous. Moh and Associates, Inc., having been appointed as the GESC, has continued to devote much of its available resources and expertise to carry out this task.

II. GESC'S Task during the Design Stage

In the design stage, GESC reviews the detailed design rendered by the Detailed Design Consultants (DDC). For each construction contract, the review procedure normally proceeds in four stages (i.e., the First, Second, Final, and Original Review submissions). In the process of review, GESC concentrates on the checking of the design reports, calculations, contract drawings, geotechnical design summary reports, special provisions, bill of quantities and other tender documents. Particular attention is focused on the review of the retaining wall design, groundwater control, flotation check, liquefaction analyses, building protection, bearing capacity, settlement, selection of geotechnical parameters, and others. Contract Drawings are carefully reviewed, devoting much attention on boring log information, instrumentation layout and details, temporary works design criteria, pressure diagrams for diaphragm wall design, dewatering specifications, building protection, extent of influence zone, diaphragm wall design, strut loads, slurry wall toe levels, ground improvement provisions, and others. GESC checks in detail

the contents of the geotechnical design summary report and special provisions, as these documents are extremely important references in the execution of the contract.

GESC's design review is concluded with the submission of the geotechnical design review report. This report contains the summary of all essential information of geotechnical concern for each construction contract. Key features of the design and important geotechnical issues which were tackled during the design review are emphasized. Potential geotechnical problems during construction are described and advise on measures to minimize or prevent failures in order to ensure safe and well-constructed structures are provided for DORTS engineers' guidance during construction.

III. GESC's Task During Construction Stage

A major bulk of GESC's work comes during the construction stage. GESC provides expert assistance to DORTS' district project offices in handling geotechnical engineering related construction problems.

During construction, contractors are required to design various items of temporary works for DORTS approval. Before the contractor starts to implement any of these items, a fully detailed design and/or method statement are submitted for review. Geotechnical-related submissions which GESC reviews include: method of installation of station diaphragm walls including trench stability calculations and panel jointing details; method of tunnelling as well as method of ground treatment; design of temporary works for support of excavations for entrances and ventshafts including strutting and preloading procedures for station excavations; instrumentation; method of installation for pin piles as part of temporary bracing/decking; method of performing ground treatment for crosspassages and sumps, building protection methods; additional site investigation; and others. In effect, GESC's review task during the design stage basically continues during the construction stage.

Monitoring stations are set up in each design lot, where the GESC can directly work with the DORTS site engineers in supervising the installation of instruments. During construction, readings or data based on specified monitoring frequencies are collected, processed and then stored in the Integrated Data Storage Center (IDSC) where the GESC can interpret and analyze them in a systematized and more efficient manner. As a means of asssuring the reliability of the monitoring data, spot-check readings are consistently made by the GESC.

IV. Integrated Data Storage Center

Following the concept of "Observational Approach" as suggested by Peck in 1969, the implementation of an appropriate geotechnical instrumentation and monitoring system for the TRTS is considered critical. Significant efforts have been invested by GESC to develop project guidelines and systems which include: establishment of procedures for various organizations to follow during design and construction; setting up of guidelines for selection of instruments for compatibility with the system requirements; preparation of specifications and other contract documents related to monitoring; and planning the project system to gather/transmit/report/store/analyze monitoring data.

Contractors are required to monitor all of the instruments according to the designated frequencies and to submit results to DORTS on a daily basis. The GESC is responsible to store all the data, make independent analyses and provide necessary advise to DORTS. It is estimated that approximately more than 30,000,000 items of monitoring data will be collected during the TRTS priority network construction. Establishing and operating a computer-based data processing system to handle all these data is obviously an important task.

GESC has set up a data processing system for TRTS geotechnical instrumentation and monitoring program. The data processing system mainly consists of an Integrated Data Storage Center located at GESC's office and at different monitoring stations located at the sites.

Since most of the TRTS instrumentation data are manually collected, site engineers have to key-in almost all readings into computers on a spreadsheet report. A "macro" has been designed for each instrument so that engineers are required to spend only a minimum amount of efforts to key in the readings. The processing code calculates the results, generates the report, produces a condensed file that can be used to transmit the data to the IDSC, stores the data in the monitoring stations' data base, and makes a comparison sheet showing abnormal readings or readings reaching alert levels and action limits. The specified alert levels and action limits of each instrument are established for the purpose of signalling proper actions which should be taken by site engineers. In general, once the alert level is reached, site engineers will check the readings, take more frequent readings, review the analyses and be ready to take approprite actions. Once the action limit is approached, certain construction activities may have to be changed and additional building protection measures may have to be implemented.

The data base system which the GESC has developed includes storage, retrieval, display and maintenance as its major functions. Engineers can readily recover data for any instrument during any period from this data base to carry out analyses or to plot according to specified format. The data transmission between the IDSC and the monitoring stations are through the PIPMAIL (Public

Information Processing) system which is an electronic mail system provided by the Directorate General of Telecommunications of the R.O.C. All monitoring stations are required to pack all the data into one file and send this packed file into the "mailbox". Engineers at the IDSC will get this file from the "mailbox" and then put the data into the data base of the IDSC. Without this program, it would be extremely difficult to systematically and economically gather all data from so many job sites.

IDSC handles all TRTS data collected from different monitoring stations. The data base system at IDSC is exactly the same as that used in each monitoring station except that the IDSC data base deals with much more data than any individual monitoring station. IDSC is also responsible for the back-up of all the data of the TRTS. In addition, more advanced, sophisticated and systemwide analyses will be conducted at the IDSC whereas only some basic and simple analyses related to a limited area can be carried out at the monitoring station level. IDSC is also the control center to dispatch monitoring data to relevant organizations of the TRTS project.

V. Advise on Systemwide Issues

The TRTS project covers a very large area and certainly, there are geotechnical-related aspects of the work which must be handled in a unified or systemwide approach. These systemwide issues have critical impact on the TRTS design and construction and should be handled through careful evaluation of the problems and expert advise from international technical consultants. The GESC has initiated certain studies in line with systemwide issues. With the available data from past geotechnical projects of MAA, additional soil investigation, and other data from published literatures on local soil behavior, international technical consultants have been able to carry out more thorough analyses of certain geotechnical problems relevant to the design and construction of the TRTS and have provided expert recommendations regarding systemwide issues. These works have been done with the full support of the GESC engineers. Some of the works are listed as follows:

1) advice on possible claims due to changed ground conditions
2) recommendations on systemwide approach to building protection
3) technical feasibility of soft ground tunnelling within the Sungshan formation using NATM
4) evaluation of the liquefaction potential of the Sungshan deposits
5) analysis of the stress-strain-strength characteristics of the Sungshan cohesive soil deposits
6) SHANSEP modelling for the Taipei cohesive soil deposits for design of diaphragm walls
7) analysis of the behavior of Sungshan deposits during excavation
8) study on appropriate method of analysis for TRTS diaphragm wall design
9) study of groundwater conditions in the Taipei Basin as related to TRTS construction with emphasis on the permeability of Chingmei gravels

Reports on these works have been provided to DORTS and have essentially become the basis of much of the geotechnical design works for the TRTS. Currently, the GESC is conducting more extensive research in line with the work order under Designated Task. The ultimate objective of this work is to have a comprehensive understanding of the diaphragm wall performance in Taipei.

VI. Technology Transfer

One of the major concerns of GESC's services to DORTS as well as MAA is technology transfer. In the early stages of TRTS works, the efficiency and effectiveness of GESC is the most important thing that concerns DORTS. Nevertheless, GESC has still carried out many technology transfer works through its daily operation. In addition, a series of technical lectures have been given by GESC. There has been a good working rapport between the GESC engineers and the DORTS staff. GESC has spent efforts in making the DORTS staff understand why and how GESC makes recommendations and review comments. GESC regards such format of learning-by-doing process as the best way to conduct technology transfer. As a result, some DORTS engineers' demonstration of their great advancement in geotechnical understanding has been very impressive.

In early 1992, most of the TRTS design works have been finished and construction works have started. GESC then proposed a plan to systematically carry out technology transfer. According to the plan, a one- or two-day technical transfer course is to be held every quarter. The course consists of both technical lectures and site visits. It is expected that within only a few years, the course would cover most of the major geotechnical items as well as certain important case studies related to the TRTS.

Experience in the past few years have indicated that technology transfer should be a two-way communication. It takes the willingness of the transferer to give the technology but it also requires the willingness of the transferee to receive the new technology. To receive the new technology, the engineer at the receiving end must be properly trained and armed with the necessary basic knowledge and techniques. More importantly, the receiver must have the motivation and desire to learn.

VII. Conclusion

For carrying out such a major construction project as the TRTS, the appointment of a competent consulting firm familiar with the local soil conditions and engineering practice is critical to the success of the project. Due to its very large scale and with so many organizations involved, some system

issues have yet to be perfectly sorted out by DORTS and GESC. These issues include the full automation of geotechnical instrumentations and the establishment of a monitoring instrument calibration center, among others. Nevertheless, it has been proven that the DORTS approach to set up the GESC as part of its overall organization is a right move. The contributions of GESC have been generally recognized by the DORTS, DDCs and contractors. As long as the GESC can continue working closely with DORTS on the basis of mutual respect and trust, the functions of GESC can be further enhanced as a potent force in assisting DORTS to carry out the TRTS project. The successful experience of GESC in the TRTS project establishes a good model in showing how geotechnical input can be properly integrated in a super construction project.

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