Case Studies of Applicability for Selection of Construction Method for Highway Underground Crossing Transit on the Deposit soils in Urban Project in Korea

Etude de cas du choix de la méthode de construction pour un croisement souterrain d'autoroute sur sols meubles dans une zone urbaine en Corée

Yang T.-S.
Dept. of Civil Engineering, Kimpo University, Republic of Korea
Yoo N.-J.
Dept. of Civil Engineering, Kangwon University, Republic of Korea
Kim S.-J.
Civil Technology Team, Gyeonggi Innovation Corporation, Gyeonggi Province, Republic of Korea
Hwang Y.-C.
Civil and Environmental Division, Yooshin Engineering Corporaion, Seoul, Republic of Korea

ABSTRACT: Recently various types of underground space have been developed steadily in the urban area; construction of new underground space interfered often with existing facilities and structures above and under ground, and many difficulties during construction occurred. In the case of underground works maintaining existing facilities, the design standard for selection of construction method would be needed to build more economical and rational underground crossing structures by removing the expected problems in advance. Although many trenchless methods of constructing a highway underground crossing have been developed and used so far, several difficulties in choosing a proper construction method have been encountered with consideration of characteristics of each construction method and the site condition. The aim of this paper is to discuss the rational guideline for selecting an appropriate construction method out of many trenchless methods through a case study in Korea, constructing a road tunnel under a highway at low depth, accounting for the geological conditions stability during construction.

RÉSUMÉ : Récemment divers types d'espaces souterrains ont été développés intensément dans la zone urbaine ; la construction d'un nouvel espace souterrain a souvent interféré avec des réseaux existants et des structures au-dessus et au-dessous du sol, engendrant de nombreuses difficultés pendant la construction. Dans le cas de travaux souterrains conservant les facilités existantes, un processus normalisé pour le choix de la méthode de construction est nécessaire pour construire plus économiquement et rationnellement des structures de croisements souterrains en éliminant par avance les problèmes attendus. Bien que de nombreuses méthodes de construction sans tranchées d'un croisement souterrain d'autoroute aient été développées et utilisées jusqu' à maintenant, plusieurs difficultés de choix d'une méthode appropriée de construction ont été rencontrées du fait des caractéristiques de chaque méthode de construction et des conditions du site. L'objet de cet article est de discuter une procédure rationnelle pour choisir une méthode appropriée de construction parmi de nombreuses méthodes sans tranchée, à partir d'une étude de cas en Corée, consistant en la construction d'un tunnel routier au-dessous d'une autoroute, prenant en compte les conditions géologiques et la stabilité pendant la construction.

KEYWORDS: Design standard, Underground passing, Urban project, Highway crossing

1 INTRODUCTION

NATM (New Austrian Tunneling Method) has been widely used in Korea for tunnel construction. The main feature of NATM is to utilize all available means to develop the maximum self-supporting capacity of the surrounding rock or soil itself, and to undertake investigation and monitoring during construction to provide the stability of the tunnel. If undetected worse ground condition is encountered, the strengthening works will be carried out to ensure safety. In this case study, the ground at the entrance of tunnel was revealed to be silty sand contained a lot of core stones during portal excavation, not just as the weathered and soft rocks as originally predicted before design. Thus the tunnel face collapsed with water spouting, and the upper ground surface was also sunk at the same time. The remediation measures including ground grouting, tunnel reinforcing and invert lining were then implemented and completed successfully(Han, 2012).

Recently many problems in the geotechnical engineering aspect have been raised as various kinds of underground space have been developed steadily in the urban area. In particular, for underground space in urban area, construction of new underground space interfered often with existing facilities and structures above and under a ground and many difficulties during construction occurred. In the case of building road or railway under a ground, maintaining operation of existing facilities, the design standard for selection of construction method would be needed to build more economical and rational underground crossing structures by removing the expected problems in advance of construction works.

Although many trenchless methods of constructing a highway underground crossing have been developed and used so far, several difficulties in choosing a proper construction method have been encountered with consideration of characteristics of construction methods and the site conditions. This paper is to discuss the rational guideline for selecting an appropriate construction method out of many trenchless methods through the case study of Gwanggyo Project known as the typical example of urban project in Korea, designing and constructing the road tunnel under the highway on the deposit soil at a relatively low depth of underground. Considering geological condition, stability during construction, and economic efficiency, the trenchless method applied to this project is selected and discussed in this paper.

2 SITE SITUATION

2.1 *Status of construction markets*

Related to the tunnel market in both Korea and abroad are carried out using the field test and lab test. Although studies on the maintaining the standard design of improved items are not totally carried out, this is not yet enough to present accurate comparison criteria since it is difficult to standardize the property of the underground condition and the operation of work situation in the field.

The promotion of domestic and foreign projects is seemed to overcome the current business difficulties of the construction industry in Korea by the slow growth of the domestic market. The government has shown considerable interests in the strategic approach of promoting construction projects for development of trenchless methods.

Table 1 shows the status of construction on railway crossing tunnel of Japan since 1986 and road tunnels market of Korea recently in both quality and quantity. As the construction market works on a cycle in an urban area, the market changes are pretty good for works of trenchless tunnels. When the construction cost of trenchless method is increasing as shown, the strength of technology development will be greater in the future. When the comparison of both methods is concerned, several construction methods using trenchless are various according to the changes of technology methods.

Table 1 Status of construction on railway and roads market

Item	Open cut method	Trenchless method	Remarks
No. of works	47	72	Japan railway
Construction cost(assumed,$)	-	133million(D) 223million(F)	Korea roads

* D: Domestic market, F: Foreign market(predicted)

Table 2 shows the distribution ratio on railway construction of trenchless method in Japan. According to the width of the trenchless method, less than 10m is composed of about 50%. It seems that trenchless methods are applied to mainly small tunnels. According to the length of the trenchless method, between 10m and 20m is composed of about 50%, also applied to mainly small tunnels.

Table 3 shows the distribution ratio on railway tunnel construction of trenchless method in Korea. According to the width of the trenchless method, less than 15m is composed of about 50%. It seems that trenchless methods are applied to mainly small tunnels. According to the length of the trenchless method, between 10m and 20m is composed of about 50%, also applied to mainly small tunnels.

Table 2 Distribution ratio on railway construction of trenchless method in Japan

Width (m)	<10	10-20	20-30	>30		
Ratio (%)	48	39	10	3		
Length (m)	<10	10-20	20-30	30-40	40-50	>50
Ratio (%)	17	49	11	9	4	10

Table 3 Distribution ratio on railway construction of trenchless method in Korea

Width (m)	<5	5-10	10-15	15-20	20-25	>25
Ratio (%)	9	32	26	9	14	10
Length (m)	<10	10-20	20-30	30-40	40-50	>50
Ratio (%)	29	42	21	9	6	3

2.2 *Status of Gwanggyo Project*

Fig. 1 shows the field status, where Located at the best place of Gwanggyo Mountain across Suwon city and Yongin city, Gwanggyo Techno Valley (Project Agency : Gyeonggi Urban Innovation Corporation) will be the center for the best science technology, research and culture of the future. The Green Network System, nature-friendly city planning, will lead to environment-friendly business park of advanced countries that links business and residence together in the southern part of Seoul, Korea. Kyungbu Expressway takes traffic for South-North, Youngdong Expressway for East-West, Youngdeok-Yangjae Expressway for metropolitan traffic and Uiwang-Gwacheon and national highway 42 & 43 lines for adjacent areas, by which traffic in the area connects each other. A two-lane traffic tunnel was to be constructed under the expressway where many vehicles pass daily.

Figure 1 Field status in an urban area

The road tunnel construction is the scope to fulfill the several important criteria of implementing construction projects in developing regions, including the safety for gaining investment profits, the possibility of implementing construction projects on the gradual basis, the possibility of using the facilities after the project completion. is the most feasible method for Korean companies to promote their businesses in the construction market.

2.3 *Status of construction mehods*

A 2-lane traffic tunnel was to be constructed under an expressway where many vehicles pass through 2 conventional trenchless methods(UPRS, PRS) and PSTM method were used in the initial design, in which are applied to the structures such as underpass box #3, #5, underpass #4, Hadong IC ramp, respectively, in Fig. 2.

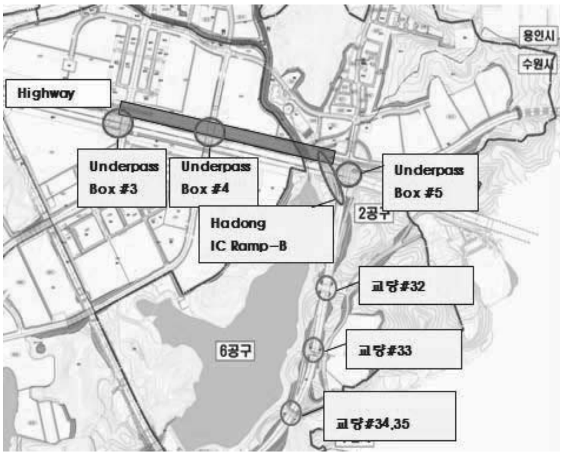


Figure 2 Location map of construction methods

The former is Upgrade Pipe Roof Structures, which is interconnected to steel pipes to propel the pipe through guidance rail in direct type. Pipe Roof Structures method means that it is interconnected to steel rods in steel pipes to be filled with reinforced concrete inside the pipes by strengthening lateral stiffness. The latter is Pressurizing Support Tunneling method, in which applies the pressure larger than the magnitude of the relaxed earth pressure around excavated area to the ground so that radial deformation occurred during excavation can be recovered.

In addition, temporary structural system for a trenchless method was introduced. This structural system is a type of hybrid member (STS method, Steel Tube Slab method) consisting of mortar-filled steel tubes laterally connected by headed reinforcements without disruption of the surface.

However, before the excavation was started, it is included a very thin overburden thickness of 0.9 m. The road construction under highway is the area to fulfill the several important criteria of implementing construction projects in an urban area(Kim, D., 2012).

On geotechnical condition, weathered ground is more than 30m thick under the upper highway. Fig. 3 shows the shape of the load-deformation curve in tunnel, in which IE indicates the support pressure of support installed at D in conventional tunnel methods and its corresponding radial deformation at final stage is OI, while as support pressure increases to I'E', resulting in decrease of radial deformation to OI' (Daemen, 1977).

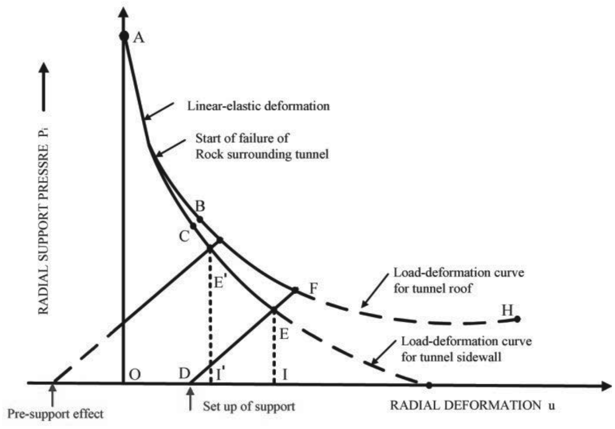


Figure 3 Load- deformation curve

The tunnel construction, in which steel pipes are installed to surround the tunnels, then soil nailing is placed at face to retain the ground as temporary retaining system, follows excavation. H-beams are installed and cement milk is injected into the pipes to support the ground, and finally shotcrete is sprayed, and the concrete inner linings are casted (Kim, D., 2012).

3 RESULTS OF MONITORING

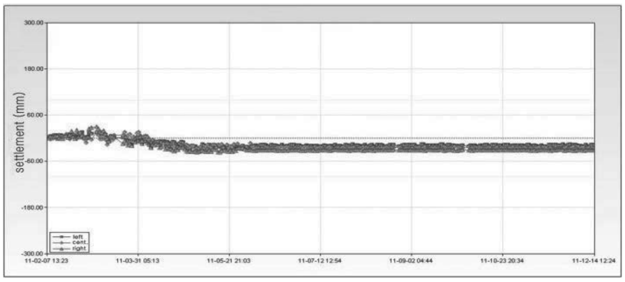
To minimize the inconvenience at existing equipment operation, many trenchless methods have been developed and used much. Existing trenchless methods insert stiff structure (rectangular type pipes or circular type pipes) to lower part under the ground in order to protect existing roads or structures before excavation of tunnels. These stiff structures are assembled each other in the lateral direction. And then, the lower part of this stiff structure will be excavated. These kinds of existing method are developed from the concept which huge inserted steel pipe-concrete structures control the displacement by supporting the overburden load. To minimize the displacement, and to increase the stiffness of existing structures, the structures are becoming larger and larger to be many obstacles. These obstacles are concerned with excavating and grouting the foundation, excavation delay on hard foundation, waste of work costs which is caused by excessive section, and long period of construction (Han, 2012).

It should be noted that another tunnel was constructed by a conventional trenchless method right next to the tunnel by PSTM. As shown in Table 4 and Figure 4, a couple of faults were created and significant ground settlement up to 30 cm occurred in the area where the conventional method was used, due to pipe jacking and excavation under construction (Kim, D., 2012).

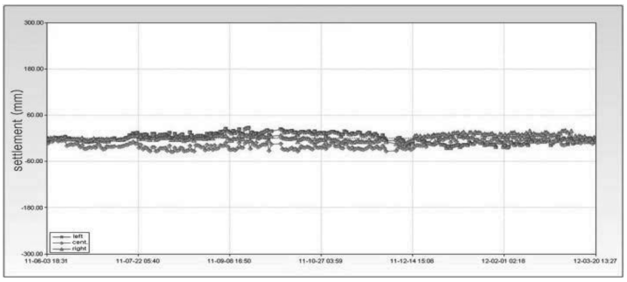
Table 4 Comparison of ground displacement(settlement)

Method	Under excavation (Max, mm).)	After excavation (mm)	Remarks
PSTM	24.0	1.0	Measured
	2.15	0.88	Calculated
Other	49.7	35.0	Measured

As the time elapses in Figure 4, the actual ground displacement state of tunnel was more than predicted in design.



(a) Underpass box #3



(b) Hadong IC-Ramp

Figure 4 Location map of construction methods

4 CONSIDERATIONS OF DESIGN STANDARD

If the highway crossing tunnel on weathered deposit soil is evaluated unsafe, it should be redesigned to improve the safety. To perform proper evaluation regarding some purposes and methods, evaluating methods of tunnel safety should be compared. Settlement, displacement, stability are not enough to be evaluated for tunnel stability according to Tunnel Design Criteria in Korea (MLTM of Korea,2007; Bjorn, 2011).

Therefore, coded techniques of the information of trenchless tunnel should be introduced considering above contents of construction types and evaluation methods in manuals as in Table 5. For more detailed maintenance, information of tunnels should be filed through the coded numbers of structure types and locations, design and construction conditions, geotechnical data, tunnel section, settlement, safety inspection, etc.

Table 5 Coded techniques of tunnel construction

Items	Code	Detailed items
Geological investigation	L-G-1	Geotechnical data
	L-G-2	Drainage etc.
	L-G-3	Standard related
Design	L-D-1	Analysis, Planning
	L-D-2	Stability of structure
	L-D-3	Design drawings, etc.
Excavation	L-E-1	Excavation equipments
	L-E-2	Monitoring
	L-E-3	Ground settlement
	L-E-4	Unstable condition
	L-B-5	Soil layers , etc.
Construction	L-C-1	Support
	L-C-2	Concrete lining
	L-C-3	Reinforcement, etc.
Operation & maintenance	L-O-1	Facilities
	L-O-2	Slope around bell mouth
	L-O-3	Safety inspection
	L-O-4	Monitoring, etc.

Design standard-based system of trenchless tunnel, which is defined as single source responsibility for design and construction, has been widely used in large public works in Korea since the government launched plan in 1996. However, as large market share of design and work volume are becoming hot item in construction sites. To measure the efficiency of global design standard-based system for the improved system by assessing domestic design projects using information about equipment, quality, and new technology adoption from case projects of highway crossing tunnels including modifying design standard.

5 CONCLUSIONS

In this study, a case history of the underground trenchless tunnel for the highway crossing in urban area of Korea is reviewed. Several points were summarized form the case history as the following.

The actual ground state of tunnel was worse than predicted in design. The remediation measures included ground and tunnel reinforcing by grouting method and reinforced grouting method, respectively, and invert constructing using steel-reinforced concrete lining, particular in highway crossing tunnel.

Existing trenchless methods insert stiff structure (rectangular type pipes or circular type pipes) to lower part under the ground in order to protect existing roads or structures before excavation of tunnels.

Design standards of newly developed trenchless tunnel technology have to specify retainment of history files of structures, coded system of failure types of structures, reliability analysis for geotechnical data determination. Owing to change of design considerations according underground condition, revising contents of design guidelines of tunnels should be followed after comparisons of design manuals for other upper and lower structures, such as foundations, concrete structures, retaining walls, etc.

6 ACKNOWLEDGEMENTS

This work is also a part of the result from the “Maintenance of Foundation Design Criteria under the Construction Facilities for Standardization”, the “Construction & Transportation R&D Policy and Infrastructure Project.

7 REFERENCES

Bjorn, N. (2011). Hard rock tunneling with particular focus on deep subsea tunnels in difficult conditions, Lectures for New Horizons by eminent scholars, Korea. 10-25.

Kim, N.Y., Yang, T. S., Woo, S. B. (2012). A case study on the excessive displacement of rear face under construction road tunnel in Korea, 3rd International on New Developments in Soil Mechanics and Geotechnical Engineering, 109-115.

Han, S. S, (2012). A Study on pressurizing trenchless method for displacement control, Master degree Dissertation. Dongyang University, Korea. 4-35.

Kim, D. Y., Lee, H. S. and Sim, B. K. (2012). Development of trenchless tunneling method using pressurizing support and its field application, Proceedings of the spring conference of the Korean Geotechnical Society, 239-254.

Daemen, J.J.K.(1977), Problems in tunnel support mechanics. Underground Space, Vol.1,p.163-172.

MLTM of Korea (2007), “Manual for design standard of tunnel”, published by Korean Ministry of Land, Transport and Maritime Affairs, 26-122.