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A field case study on construction of underground passageway with non-open excavation method

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ABSTRACT: In this study, the construction process of non-open excavation cases using DSM and TRCM and the field monitoring during construction stage are introduced and the applicability and the stability of the applied method are reviewed. The problems occurred in the fields are drawn out and the settlement profiles of the tunnels during the construction stages are analyzed using the field monitoring results. Although both methods are applied successfully in the site, it was recognized that some complementary measures are necessary to prevent the settlement in soft clay layers. In the future, the usage of non-open methods will be more expanded at the urban areas. The findings in this study would be a good reference for underground passage way installation.

1 INTRODUCTION

In metropolitan city area, subway stations are often existed or planned. Hence, there is a trend that the private owners of high rise buildings adjacent to the major streets try to install small underground passageways to connect the subway station and their basement floor of the buildings. This is a way of providing the convenience for the transient population and increasing the value of the buildings.

However, there are many difficulties and limitations in the administrative regulations and the technical solutions for installing the underground passageways. Two technical problems installing underground passageway are: 1) the installation must escape the underground utility lines, e.g. storm water and sewer pipelines, electricity and gas lines, etc., 2) It is necessary to construct the passageway, while the peoples and the vehicles are passing on the road above. Non-Open Excavation Method is a way of solving these problems for installing underground passageways.

DSM (Divided Shield Method) is a non-open excavation method developed from the Messer Shield method by improving the size and the shape of Messer plate in order to reduce the ground displacement and to ease the penetration of the plate into the ground.

TRCM (Tabular Roof Construction Method) is another non-open excavation method, in which steel pipe is installed using hydraulic jack. After pipe jacking, the soils within the pipe are excavated and the upper/lower concrete slabs are installed for completing the structure.

These methods have ads/disadvantages according to the ground conditions, the shape of the structure and the peripheral situations. There are some difficulties to understand the characteristics of stress and strain behavior of the structure of interest, since the conditions of the design and the construction in the field are different.

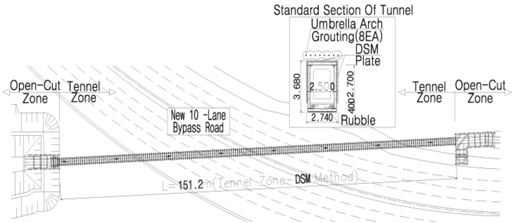
In this study, the construction process of non-open excavation cases using DSM and TRCM and the field monitoring during construction stage are introduced. The applicability and the stability of the applied method are reviewed. The problems occurred in the fields are drawn out and the construction stages are analyzed using the field monitoring results.

2 CASE 1: DSM APPLIED SITE

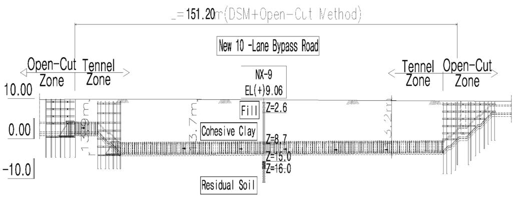
2.1 *Site conditions & plan*

The site is located at Magok dong in the western part of Seoul. It is composed of a vacant area and a temporary bypass road. some settlements are expected to occur during the construction, since the site is composed of the soft clayey soil. If settlement would not affect the stability of the underground structure significantly, DSM is thought to be appropriate to be selected as a cost-effective method.

DSM is applied at the point where the tunnel is passing under the temporary bypass road. The tunnel is 151 m long and at the starting and ending points, where no significant structure is located, open cut method is used. The plan and section drawings are shown in Figure 1. The installation depth of DSM is about 13.2∼13.9 m from the surface and the tunnel is located at the lower part of clay layer. At the design



(a) plan view



(b) section view

Figure 1. Construction plan for DSM site.

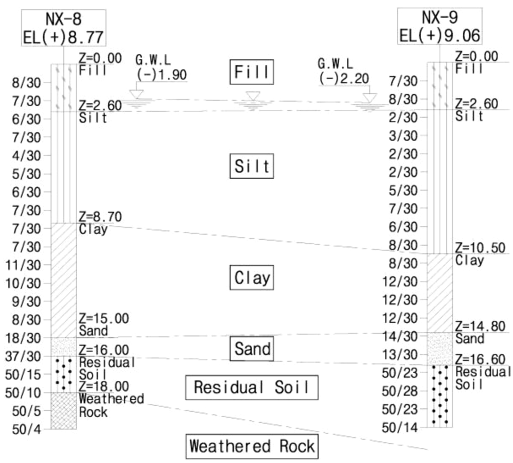


Figure 2. Geotechnical profile of DSM site.

stage, there were some worries of fluidized soil inflow and the excessive settlement.

After DSM construction, a box structure of the size 2.1×3.1 m is planned with the tunnel. At the front of DSM tunnel face, multiple steel pipe grouting using the pipes of Dia. = 60.5 mm, t = 3.2 mm are installed at the spacing of 400 mm and 8 layers in order to prevent the influx of fluidized soil.

The groundwater level of the site is very high and the ground are composed of very soft to soft silt to 10.5 m deep and soft clay to 15 m deep (Fig. 2).

2.2 *Construction procedure*

2∼3 tunnel supports are constructed per day in the spacing of 0.9 m and the advance rate was 1.8∼2.7 m/day. Total construction days were 140 days including rest period. In the initial period of construction, the influx of groundwater with soft soil gave difficulties in construction. Figure 3 shows the situation of trouble for arranging the bottom of the tunnel due to large influx of the soft soil and water.

Figure 3. Influx of tunnel groundwater and soils during excavation.

Figure 4. Relaxation of protection board at the bottom of tunnel face.

Figure 4 shows the situation that the protection board is released at the bottom of the tunnel face due to fluidized soil influx.

The measures for solving this problem is to increase the number of the multiple steel pipe grouting from 8 layers to 13 layers to protect the tunnel face and the grouting work was extended from starting point to whole length of the tunnel. The depth of the tunnel depth is down to 18.4∼19.1 m from the surface and laid down to residual soil layer. This way of counter measure has a disadvantage of the utilization of the passage way since the tunnel location becomes deeper than that of the original plan and the decision was made for the safety of the construction.

Figure 5 shows the dried soil conditions during excavation since the soil layer become better as mentioned by Boscardin & Cording (1989). Figure 6 also shows the condition of the tunnel face during excavation after increase of tunnel depth and the change of the soil reinforcement. The advance rate was increase from 0.9∼1.8 m/day before the countermeasure to 1.8∼2.7 m/day.

Figure 5. Status of excavation at tunnel face after counter measure.

Figure 6. Status of protection board after design change.

2.3 *Field monitoring in DSM site*

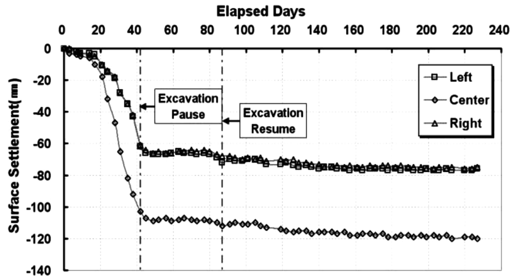
Field measurement instruments installed at this site were strain gages to analyze the status of the stress within the tunnel supports and surface settlement gages to analyze the settlement behavior of soil over the tunnel. The settlement gages are at the location of starting, center and ending points. However, the strain gages are damaged due to worst working conditions.

Figure 7(a), (b) & (c) show the longitudinal tendency of the settlement for three locations mentioned above. Center is the center line of DSM at the surface and the left and right points are located 3 m apart from the center line to transverse direction. The settlement device at starting and ending points are 10 m apart from the inlet and exit points of the tunnel.

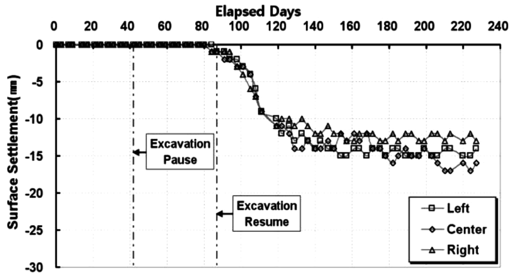
According to Figure 7(a), large settlements of are recognized due to the influx of fluidized soils to the tunnel. Even though the separation distance of the settlement device to transverse direction, the settlement in center line was large to 120 cm.

Figure 7(b) and (c) shows the tendency of settlements at the center and ending points of the tunnel. At these locations, excavations were made after countermeasures are executed for soil and groundwater influx.

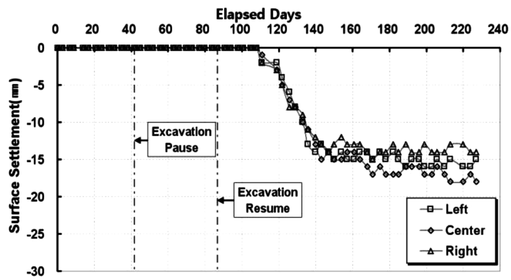
Settlements are restricted to about 16∼18 mm at both locations and the difference of settlements to transverse direction was negligible.



(a) at the start



(b) at the center



(c) at the end

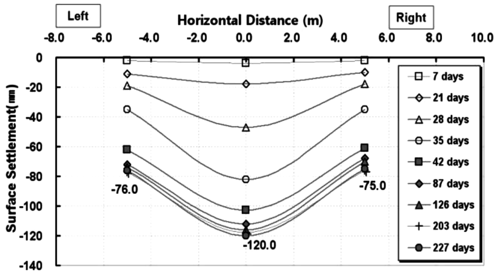
Figure 7. Longitudinal profile of settlement for various locations in DSM site.

Figure 8(a), (b) & (c) show the trend of surface settlements to transverse direction at three locations. In Fig. 8(a), settlements increase significantly from the initial period up to 120 mm in the center line within 7 weeks. The settlements are stabilized thereafter. According to Figure 8(b) and (c), initial settlements are still high. But the settlements occurred within 16∼18 mm and showed a favorable behavior after protective measurements are launched.

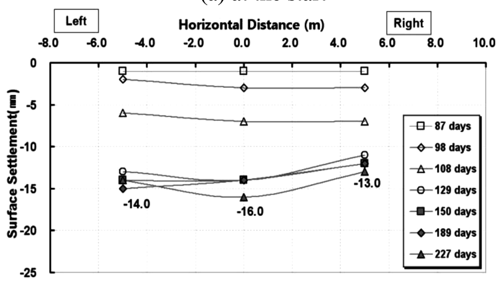
3 CASE 2: TRCM APPLIED SITE

3.1 *Site conditions & plan*

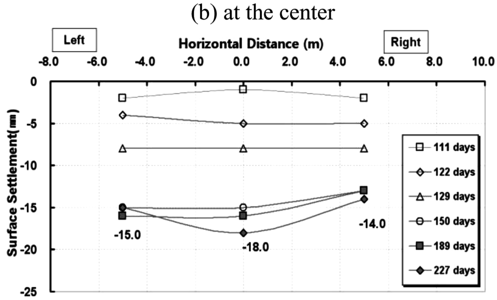
The passage way construction of interest was done for connecting from the commercial building at the south to subway station at the North. TRCM is applied at the



(a) at the start



(b) at the center



(c) at the end

Figure 8. Transverse profile of settlement for various locations in DSM site.

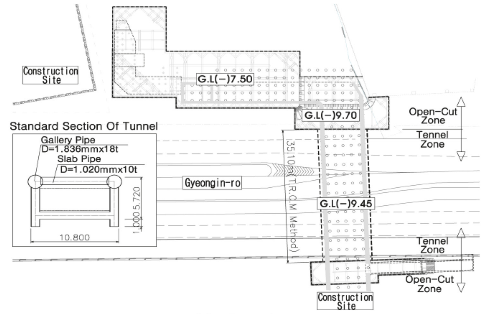
location which passes under the Gyeong-In express way. The size of passage way is 10.8 m wide and 35 m long. The plan and the section of the TRCM applied is shown in Figure 9.

The procedure for TRCM is the following:

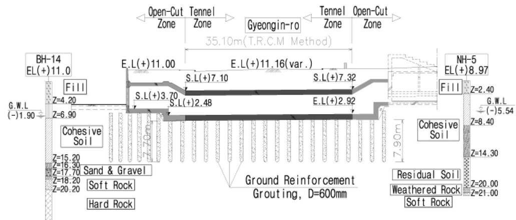
(1) A large circular pipe called gallery pipe is pushed in using the hydraulic pressure to the longitudinal direction at the starting and ending points of planned section. The soil within the pushed pipe is excavated.
(2) Within the gallery pipe, top steel plate called slab pipe is installed to the transverse direction.
(3) By excavating trench, the external walls are made using concrete. The soil within TRCM is excavated and the foundation slab is constructed

The diameters of the pipes used in this site are 1836 mm for gallery pipe and 1020 mm for slab pipe. And the circular pipe is sued for slab pipe.

The type of the soils in this site is soft clayey silt and silty clay (Fig. 10). Although some difference is



(a) plan view



(b) section view

Figure 9. Construction plan for TRCM Site.

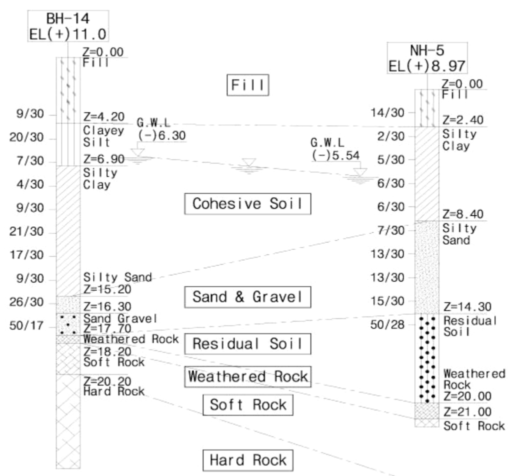


Figure 10. Geotechnical profile in TRCM site.

shown depending on the surface elevation, the structure is located where N value is 9/30 in BH-14 and 6/30 in NH-5.

The groundwater level is formed around 1.5∼3.0 m above the bottom of the structure. Since the total length of the structure is not long, specific groundwater lowering or barrier methods are not chosen and only a pumping well is made at the end of the site to keep the safety of the whole structure.

3.2 *Construction procedure*

Several photos are provided to show the construction procedure. Figure 11 shows the hydraulic pressure

Figure 11. Hydraulic pressure device and the reaction wall.

Figure 12. Press fit condition of gallery pipe.

Figure 13. Construction of slab pipe within the gallery pipe.

device with reaction wall to push in the gallery pipe for TRCM method. In Figure 12 air is blown into the pie for manual excavation after the pipe is pushed in. Slab pipe is constructed to transverse direction in the gallery pipe in Figure 13.

In Figure 14, trench is excavated to form the exterior wall after placing the steel bar reinforcement and pouring concrete in slab pipe. Figure 15 shows the supports with PC panel during the excavation of the trench.

Figure 14. Concrete pouring in slab pipe.

Figure 15. Excavation of trench.

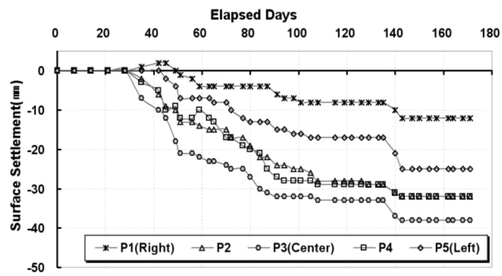
3.3 *Field monitoring in TRCM site*

The field monitoring devices chosen at this site are the groundwater level gage for groundwater level changes and the surface settlement plates at the starting, center and ending points of the structure. The groundwater level was not fluctuated significantly to the completion of the construction.

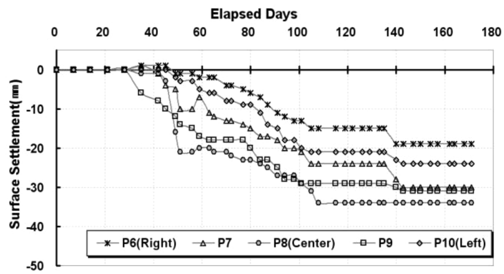
Surface settlement plates are installed one at the center line and four points by 8 m and 16 m apart to transverse direction from the center.

The settlement trends to longitudinal direction in Figure 16 shows the changes in soil behavior around 20 days after the start of construction. This is the time, when the construction of slab steel pipe is started. Continuous increase of the surface settlements are recognized until the construction is completed regardless of the interior excavation of TRCM. It seems that the pushed in construction of the slab pipe disturbed the surrounding soil and the subsequent settlements are occurred due to traffic loads on the road. It tends that usual settlements are caused by the overcutting of soils between the slab pipes during the interior excavation of TRCM.

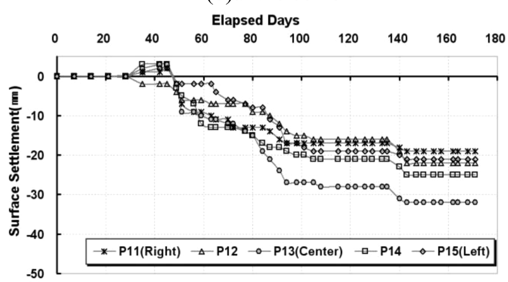
Figure 17 shows the transverse surface settlement trends at the ending point. The settlement is occurred about a half of total settlement to 77 days when the



(a)at the start



(b)at the center



(c) at the end

Figure 16. Longitudinal profile of settlement for various locations in TRCM site.

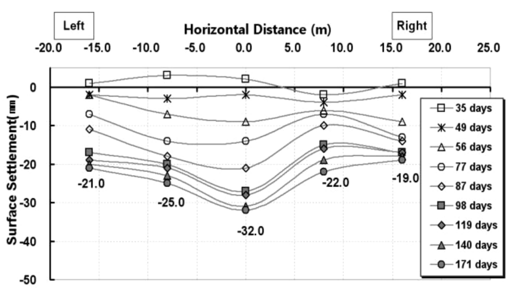


Figure 17. Transverse profile of settlement at the end of TRCM site.

slab pipe construction is completed. This settlement seems to be caused by the reduction of shear strength from the vibration and the external forces during the pushed in process of the pipe.

Figure 18 shows the results of surface settlement monitoring near to the water pipe line. This also shows the continuous settlement at the stage of the pipe

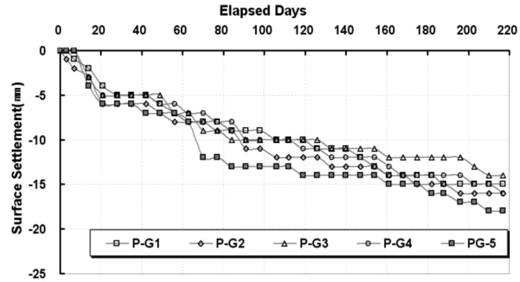


Figure 18. Settlement of water supply pipe in TRCM section.

pushed in. Although, the construction of the underground pipe line in soft ground seems to be very sensitive in settlement, the magnitude of the settlement is managed within the allowable settlement standard (Clough & O'Rourke, 1990).

4 CONCLUSIONS

Comparison and evaluation of the two examples of underground passage way construction showed some findings to improve the design, construction and management processes.

DSM is frequently selected as an underground passageway construction method in various soil conditions, since it is inexpensive in construction cost and the work process is simple. However, in the soft soil with high groundwater level, large settlement is occurred. It seems that some supplementary methods are needed to eliminate the problems occurred.

TRCM is known to be safe and is used quite often in Korea, although its construction process is complicate. To prevent the settlement in soft clay layer, some complementary measures are necessary for overcutting of slab pipe as well as for pushing in of gallery pipe.

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