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Case study on subsidence of the railroad of the existing operation line and countermeasures establishment for non-opencut tunnelling

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ABSTRACT

Recently, it is a widely applied method that minimizes the influence on the upper part of the structure by inserting the steel pipe which will serve as the outer wall of the line substructure and excavating the inside to form the line structure for the non-opencut tunnelling method. Underground crossing construction under the existing railroad tracks can cause displacement in the tracks, which greatly affects the safe operation of trains in the case of operating lines. In this study, about 38mm subsidence of the railroad track occurred in some sections during the construction of the non-opencut tunnel under the operation line to which the T.R.c.M method (Tubular Roof construction Method) was applied, and forensic analysis of the causes of the subsidence occurred and countermeasures were presented.

1. INTRODUCTION

The non-opencut construction method is one of the methods for constructing a structure under the existing operating line track, and forms a structure through underground work without opening a roadbed. Construction is possible by minimizing the impact on the upper part of the structure by press-fitting a steel pipe that will serve as an outer wall of the lower structure of the track and excavating the inside thereof, and the frequency of application has been increasing in recent years (Jie, 2004). In order to design and construct the optimal construction method for non-opencut construction, it is necessary to analyze the surrounding conditions and the type of operating line, the conditions of the operating section, the composition of the excavated ground, the classification of the underground transverse structure, the height of the track under the track by the planned height, and the existence of obstacles, and abnormalities according to maintenance after the formation of the underground structure in detail. Underground crossing construction under the railroad tracks can cause displacement in the tracks, which greatly affects the safe operation of trains in the case of operating lines. In this study, about 38mm subsidence of the subgrade occurred in some sections during the

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construction of the non-cut tunnel under the operation line to which the T.R.c.M method was applied, and an analysis of the cause of the subsidence and a countermeasure were presented.

2. CURRENT STATUS AND ANALYSIS OF SUBSIDENCE OF EXISTING LINES

The T.R.c.M method uses a gallery pipe with a diameter of 2,000 mm and a slab pipe with a diameter of 800 to 1,000 mm to create a non-opencut tunnel with an internal size of 5.56 m (B, width) × 6.86 m (H, height), and the extension is planned to be 300 m to minimize deformation of the upper operating line with a wall thickness of 1m at the site subject to this study as shown in Fig. 1~2. According to the time of roadbed subsidence and emergency recovery records, the roadbed subsidence is estimated to have occurred about 38mm, and it is estimated to have occurred on the left side about 3m in front of the steel pipe propulsion position.

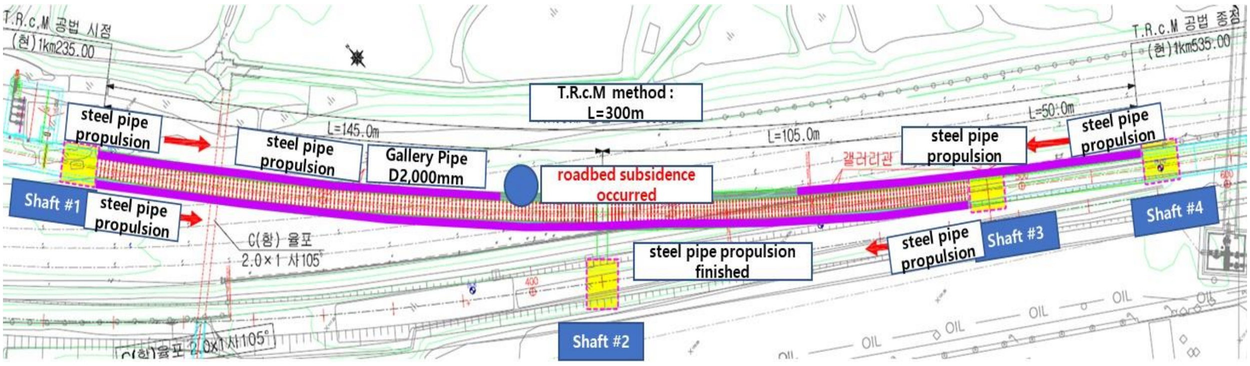


Fig. 1 T.R.c.M method planning floor plan (project layout)

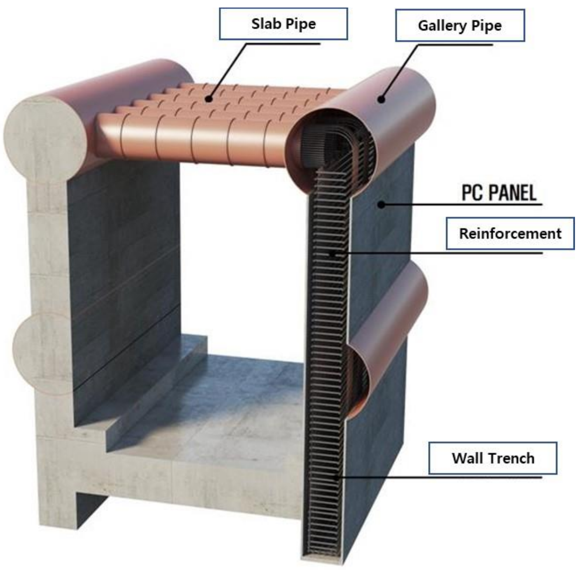


Fig. 2 typical cross section for T.R.c.M method

2.1 Site status in case of roadbed subsidence

The results of the visual inspection conducted inside the propulsion steel pipe at the time of roadbed subsidence at the site were analyzed, and the data at the time of the visual inspection are shown in Fig. 3. According to the results of a visual investigation into the steel pipe near the point where the roadbed subsidence occurred, soil inflow into the steel pipe and collapse of the excavation surface were not confirmed, but in the case of the steel pipe on the right side of the upper gallery, partial groundwater inflow was confirmed. It was found that the ground saturation by groundwater or the situation of groundwater leakage was not confirmed in the ground condition of the tunnel face.

(a) Tunnel face of left gallery pipe (b) Tunnel face of right gallery pipe

Fig. 3 Visual inspection of steel pipes

2.2 GPR exploration and result analysis

In this study, GPR exploration was conducted to identify sections vulnerable to subsidence in addition to subsidence that occurred at the site. Through GPR exploration, it was intended to estimate the presence or absence of a joint with the stratum loosening zone of the railway subgrade and lower ground and use it as basic data for ground reinforcement planning and construction. The GPR exploration survey was conducted on six survey lines, and the total length of the survey lines was 2,040.0m. In addition, the exploration was carried out using 400MHz and 800MHz dual antennas and 100MHz single-channel antennas mounted on GPR equipment in consideration of the structure characteristics, purpose of investigation, depth of inspection, and resolution of the exploration area. The unclear boundary of the bottom of the ballast and the sudden change to the bottom can be assumed to be caused by loosening, sagging, and subsidence of the ground in general as shown in Fig. 4~5.

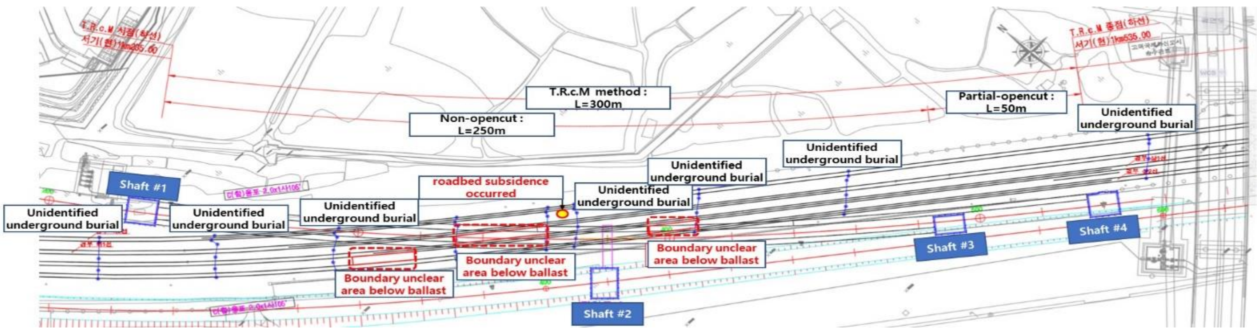


Fig. 4 Abnormal section by GPR exploration

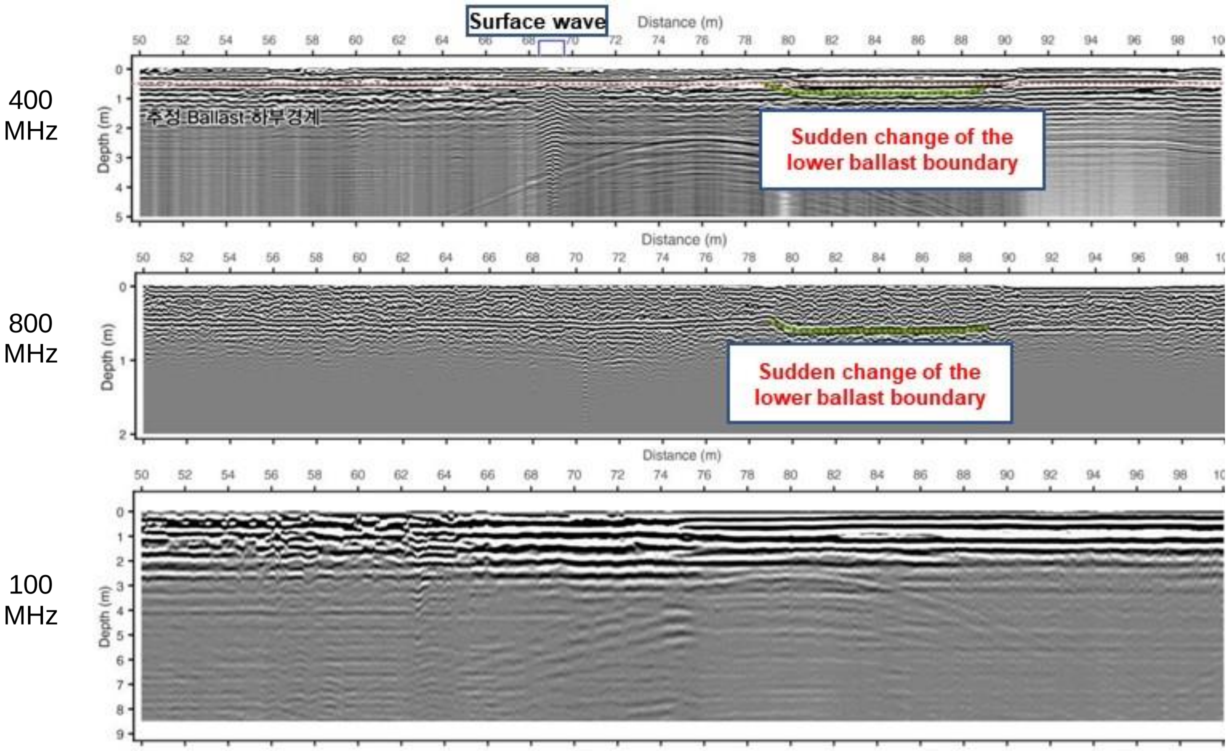
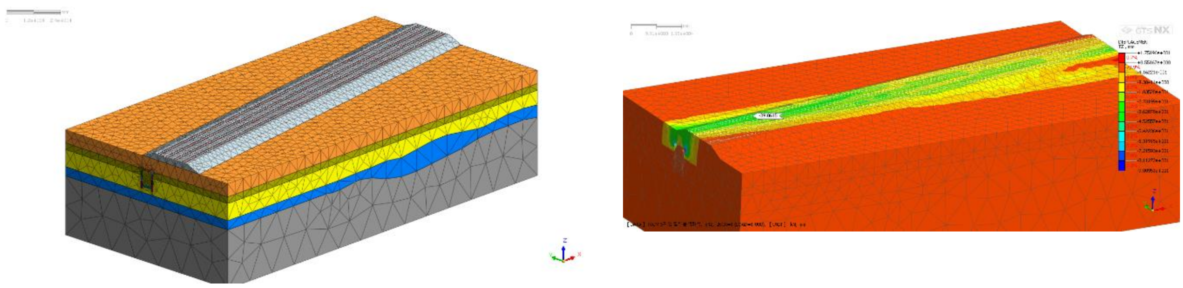


Fig. 5 Example of GPR exploration result

2.3 Inverse analysis considering settlement occurrence status and construction status

In the case of this study area, the result of numerical analysis using the ground properties determined at the time of design was expected to have occurred around 10mm, but the actual ground properties were recalculated in consideration of the actual localized heavy rain and the sinking of 30mm or more during the propulsion of the gallery steel pipe. Inverse analysis was performed to confirm whether stability was secured during future construction as shown in Fig. 6. The Mohr-Coulomb model was used, and the unexcavated tunnel section was simulated by reflecting topographical influences and changes in strata conditions, and a 3-dimensional seepage-stress coupled analysis was performed to conduct inverse analysis. The final soil properties from inverse analysis by repeated trial and error were obtained as summarized in Table 1.



(a) Entire mesh (b) Vertical displacement

Fig. 6 3D FEM analysis inverse analysis results

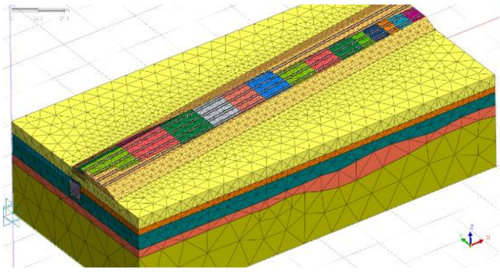
Table 1. Soil properties from inverse analysis

Types	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction angle (deg.)	Elastic modulus (MPa)	Poisson's ratio	Permeability (cm/sec)
Reclaimed sandy soil	17.0	0.5	27.0	0.7	0.38	4.0E-3
Sedimentary clay	17.5	2.0	0.0	0.2	0.40	4.5E-5
Weathered soil	18.0	10.0	28.0	25.0	0.35	3.0E-4
Weathered rock	20.0	33.0	33.0	200.	0.30	3.5E-5

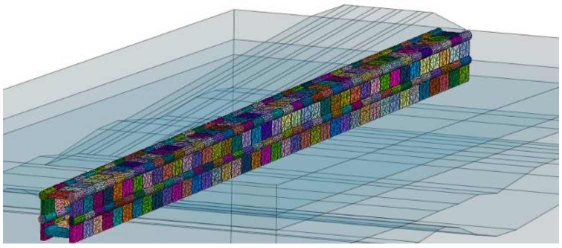
2.4 Evaluation of adequacy of reinforcement plan by 3D finite element analysis

In this study, the adequacy of the reinforcement plan through three-dimensional finite element analysis was verified to check whether the stability of the upper operation railway roadbed and the non-opencut tunnel itself was secured during non-opencut tunnel construction after ground improvement by grouting was implemented. Numerical analysis was performed using MIDAS GTS NX, and the analysis was performed by setting an analysis area of 100m left and right around Shaft #2 among the non-opencut tunnel sections by applying ground improvement by grouting at the top of the non-opencut tunnel.

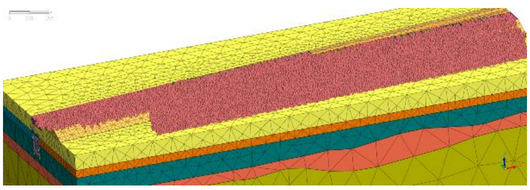
In addition, for numerical analysis, static analysis is performed to evaluate the behavior of each construction stage during the construction of the non-opencut tunnel, and after performing dynamic analysis considering the train movement load, the subsidence of the subgrade is added to evaluate the final subsidence of the subgrade of the existing operating line. Through analysis, it was reviewed that the maximum ground subsidence by construction stage of the railway trackbed and track caused by the lower non-opencut tunnel at the time of the final construction of the existing line was about 9.20mm.



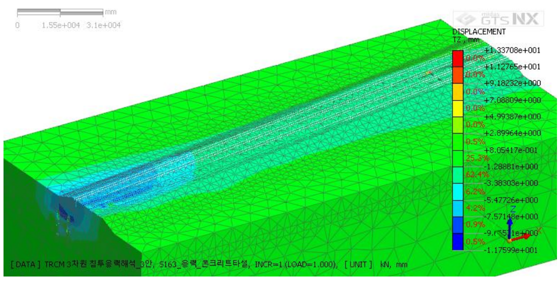
(a) Entire mesh



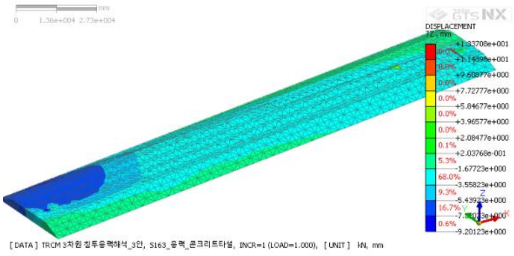
(b) T.R.c.M excavation modelling



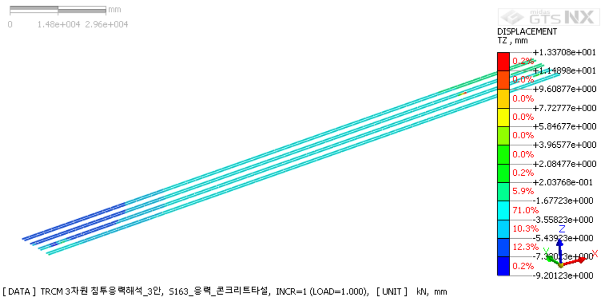
(c) Ground improvement by grouting



(d) Vertical displacement



(e) Subsidence of existing railroad



(f) Subsidence of existing track

Fig. 7 3D FEM analysis results after ground improvement

3. CONCLUSION

In the unopened tunnel at the site of this study, the deformation of the top of the tunnel is suppressed by the steel pipe, so the possibility of subsidence due to the subsidence of the top is small. Considering that groundwater inflow did not occur, the possibility of surface subsidence was judged to be low. After comprehensively analyzing the settlement vulnerability points using GPR exploration, on-site settlement measurement data, and stability analysis results during future construction using inverse analysis results, it was analyzed that the ground reinforcement of the upper soil layer of the tunnel was necessary, and the upper ground reinforcement plan was established. As for the construction method, it was judged that the micro-cement grouting method was appropriate because it could use small equipment, was excellent in workability, was economical, and had excellent water barrier and ground reinforcement effects.

REFERENCES

Jie, H.K., You, K.H. and Park, Y.J. (2004), “An application of the tubular roof construction method for seoul sudway tunnel construction”, *J. of Korean Tunn Undergr Sp.Assoc., KTA,* **6**(4), 345-356.