Fundamental Study on Minimizing Surface Settlement Induced by Pipe Roof Construction

Laboratory of Rock Engineering and Mining Machinery

OENG Han Huor

1. Introduction

Ground surface settlement caused by tunnelling in soft ground is a greatest concern in all aspects of tunnel design. In urban areas, the effect of settlement due to shallow and soft ground tunneling is hazardous to nearby buildings, infrastructures and existing services. Therefore, the pipe roof method, one of tunnelling technique, has been used over the last few decades to reduce the influence on the surrounding construction. The aim of pipe roof method is to minimize ground surface settlement and promote the tunnel stability. Many researches have been conducted to study the effect of pipe roof construction on the main tunnel. However, the surface settlement induced by pipe roof construction itself has not yet been fully understood. When applied in soft-ground tunnelling, the pipe-roof technique has similar issues. During the pushing process of each pipe roof, the natural ground is always excavated about 20-60 mm (over-cutting area) greater than the diameter of the pushing pipe. This over-cutting area is immediately filled with lubricants. Therefore, each pipe installation induces ground deformation. For this reason, this research aims to carry out a study to minimize the surface settlement which is induced by the pipe roof construction itself.

2. Research Methodology

To study on minimizing the surface settlement caused by pipe roof method, the model has been developed by using the software FLAC3D. There are several factors affecting the surface settlement after the pipe roof construction. To achieve this objective, firstly, the effect of lubricant on surface settlement was studied by introducing two shapes of pipe roof which are Gate-typed arrangement pipe roof and Horse-shoe arrangement pipe roof as shown in Figure 1. Four types of Young's modulus of lubricant were introduced: 200 kPa, 300 kPa, 400 kPa and 500 kPa. Secondly, a case study of pipe roof construction method with slurry pipe jacking method beneath the national highway in the Okinawa Prefecture was presented in order to validate the numerical simulation results. Finally, the sequences of installation of pipe roof construction were investigated in the purpose of minimizing the surface settlement.

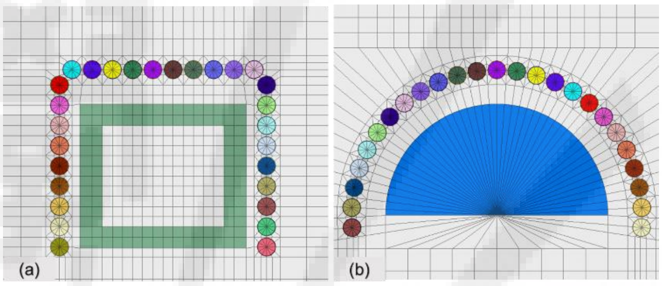

Figure 1 Numerical model of pipe roof construction
(a) Gate typed arrangement pipe roof, (b) Horse-shoe arrangement pipe roof

3. Results and Discussions

Based on the simulation results, Figure 2 illustrates the contour of displacement of Gate-typed arrangement pipe roof under different Young's modulus of lubricants which are 200 kPa, 300 kPa, 400 kPa and 500 kPa. The results reveal that an increase of Young's modulus of lubricant from 200 kPa to 500 kPa injecting in the over-cutting area can minimize the surface settlement. The higher the stiffness of lubricants is, the smaller the surface subsidence induces.

Figure 3 gives the results of final vertical displacement distribution curves of four types stiffness of lubricant after pipe roof construction were completed. As can be seen from Figure 3 (a) which is the vertical displacement distribution curve of Gate-typed arrangement pipe roof, the maximum value developed directly at the center of pipe roof's location. The maximum vertical displacement of 200 kPa lubricant is approximately 18 mm. The vertical displacement generated by using different strength of lubricants also showed the difference of approximately 3 mm corresponding to 16% by increasing the stiffness from 200 kPa to 500 kPa. Figure 3 (b) shows that the results of vertical displacement distribution curves of Horse-shoe arrangement pipe roof. The results illustrate that by increasing the lubricant's stiffness from 200 kPa to 500 kPa, the maximum surface settlement reduced 3 mm corresponding to 20% after pipe roof installation. Next, the simulation results are compared with field measurement data for verification. The results show that the surface settlement at field construction effectively reduced by adopting the new lubricant material. Finally, it can be observed that the sequences of installation have the effects to minimize the surface settlement for L-shape, Gate-type, and Horse-shoe arrangement pipe roof.

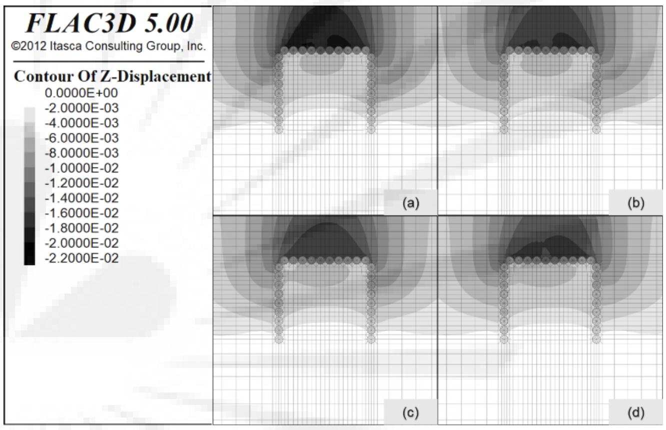

Figure 2. Contour of displacement under different Young's modulus of lubricant (a) 200 kPa (b) 300 kPa (c) 400 kPa (d) 500 kPa

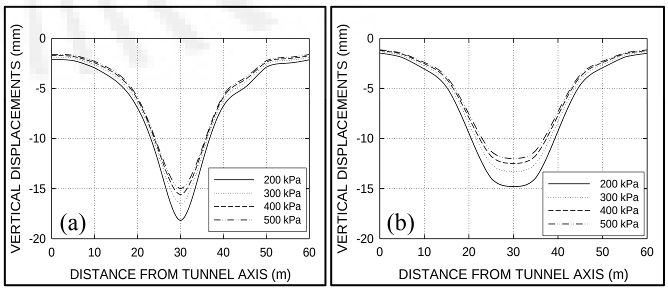

Figure 3. Vertical displacement distribution curve of pipe roof.
(a) Gate typed arrangement pipe roof, (b) Horse-shoe arrangement pipe roof