Optimization Analysis on the Design Project of Large Diameter Pipe-Roof Engineering

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Abstract. As a new type of underground engineering reinforcement technology, the pipe-roof method has shown its significant superiority in shallow buried large section tunnel engineering in high traffic urban areas. According to the two design scheme of pipe-roof engineering, the 2-D numerical analysis model has been built to analyze the ground settlement. Results shows that the maximum value of surface settlement with 970mm pipes is about 20% less than that of 800mm pipes. The pipe with diameter of 800mm has several critical limits during the construction of pipe jacking. The pipe diameter of 970mm is the optimal recommended diameter for practical operation in pipe-roof engineering.

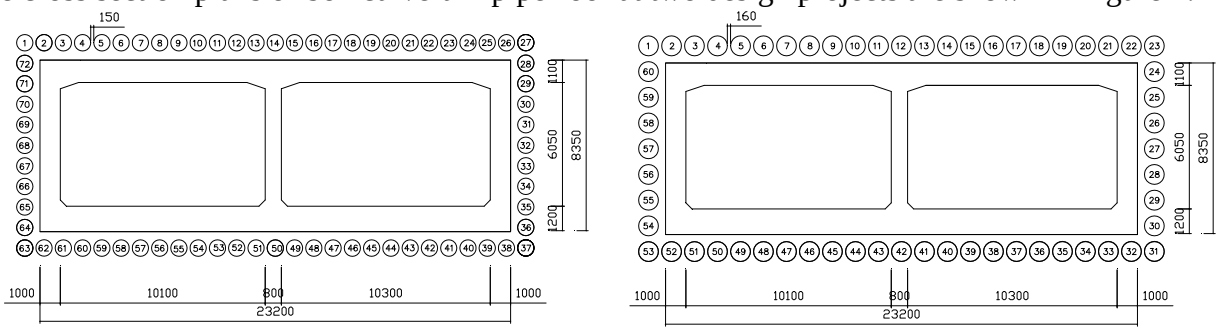
Introduction

With the development of economy, the increasing of population and the rapid urban expansion, the traffic is becoming more and more crowded in China. In order to ease the growing traffic pressure, the interchange engineering is more and more popular. As a new type of underground engineering reinforcement technology, the pipe-roof method has shown its significant superiority[1].

The earliest pipe-roof engineering is the passage of Japanese Kawase-Inae crossing railway in 1971[2]. And then several pipe-roof engineering has been built in the following years[3-5]. The first application of pipe-roof method in China is the underground passages in Hong Kong and Taiwan[6,7]. In 2004, a tunnel engineering in Shanghai middle ring line adopted the box culvert jacking method under pipe-roof[8]. In recent years, with the construction of large underground crossing engineering in China, the pipe-roof method has been well applied [9-11].

General Situation of Engineering

A tunnel project is designed by using the construction technology of pipe-roof method. The width of box culvert in pipe-roof is 23.2m and the height is about 8.5m. According to the requirement of engineering, one design project is that the pipe-roof is made up of 72 steel pipes with the diameter of 800mm around the box culvert, and the other project is 60 steel pipes with the diameter of 970mm. The cross section plans of box culvert in pipe-roof at two design projects are shown in Figure 1.



a) pipe diameter of 800mm b) pipe diameter of 970mm

Fig.1. Plan of cross section of box culvert in pipe-roof at two design projects

In order to determine the optimum project, the numerical analysis model was established for two kinds of design projects, and the simulation and comparison of surface subsidence was carried out during the construction of pipe-roof.

Analysis of Pipe-roof Design

Analysis Model. The lateral range is 125m in the plane numerical simulation model, which is more than 5 times the box culvert span. The top boundary of model is natural earth surface, and the bottom boundary of model is 30m below the bottom pipe-roof. The total height of model is about 44m, which is more than 4 times the box culvert height. The left and right boundary of model is horizontal fixed, bottom boundary is vertical fixed, and top boundary is free. The finite analysis model of box culvert in pipe-roof is shown as Figure 2.

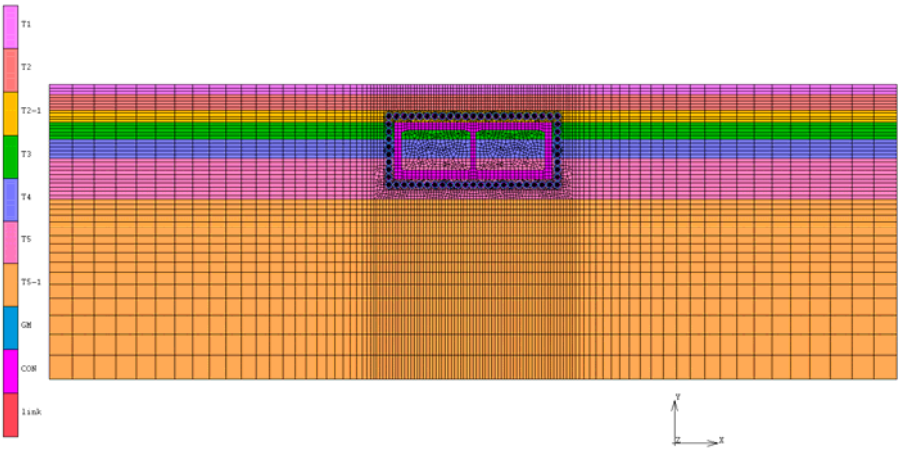


Fig.2. Finite analysis model of box culvert in pipe-roof

Mechanical Parameters. According to the geological condition of pipe-roof engineering, the mechanical parameter of soil from surface to ground is shown in Table 1, and the parameter of steel pipes is shown in Table 2.

Table 1. Physical and mechanical parameters of soil from surface to ground

Soil layers	Thickness [m]	γ [kN/m^3]	E [MPa]	μ	c [kPa]	φ [º]
Artificial soil	1.50	19.5	/	/	/	/
Mild clay	2.33	19.2	23.1	0.43	28.3	11.6
Silt soil	1.97	18.1	16.8	0.43	32.3	10.3
Fine sand	2.27	17.1	40.0	0.43	2.0	19.0
Silt soil	2.84	19.5	20.4	0.36	18.6	14.5
Medium sand	6.17	17.1	38.4	0.30	6.5	22.0
Gravel sand	/	20.4	40.2	0.36	7.0	28.0

Table 2. Physical and mechanical parameters of steel pipes

Diameter [mm]	E [kPa]	μ	γ [kN/m^3]	A [m^2]	I [m^4]
800	2.1×10^8	0.3	78.0	0.039	0.00303
970	2.1×10^8	0.3	78.0	0.048	0.00545

Results and Analysis. According to the simulation analysis, the comparative settlement curves of ground surface caused by the construction of pipe-roof with two kinds of pipe diameter can be drawn as Figure 3.

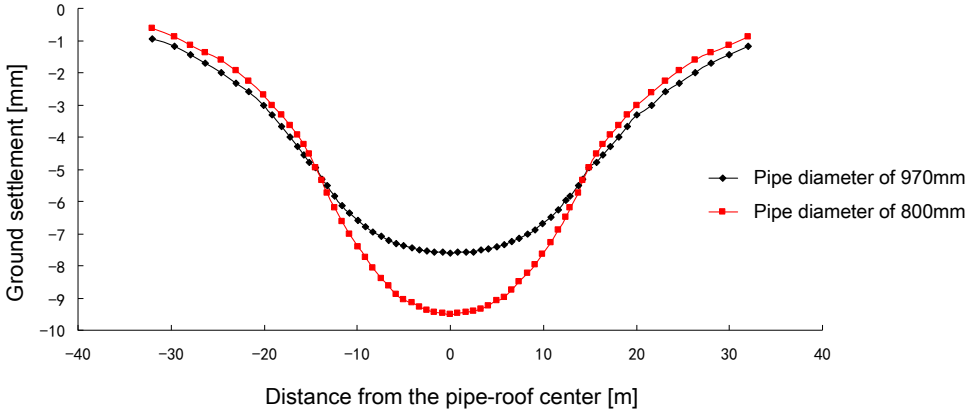


Fig.3. Comparative curves of ground settlement with two kinds of pipe diameter

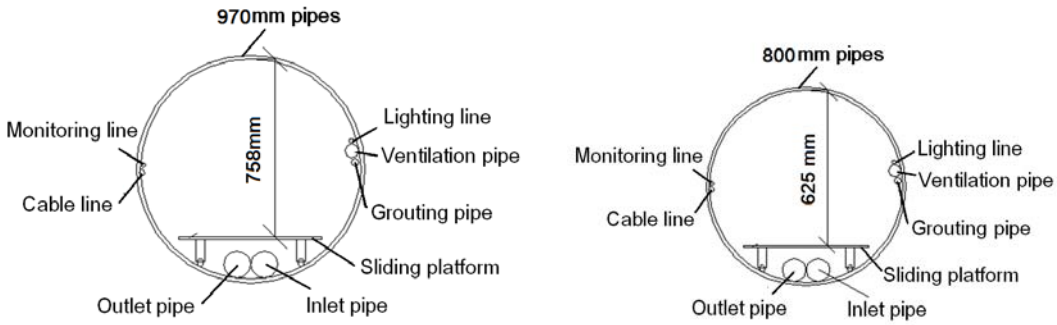
It can be seen from Fig.3 that the ground settlement mainly occurs at the middle part of box culvert, and the maximum settlement value caused by construction is about 9.4mm when the pipe diameter is 800mm. The maximum settlement value reduces to 7.6mm when the pipe diameter is 970mm. Though the absolute value difference is small, the relative deformation deduces by about 20%. On the whole, the pipe-roof with diameter of 970mm is preferred.

Analysis of Pipe-roof Construction

From two aspects of construction mechanic and deformation, the pipe-roof technology with the diameter of 800mm or 970mm can both meet the engineering requirements, and the maximum value of surface settlement is under control. While the 970mm pipes are widely applied in the construction of pipe-roof engineering by micro shield technology, and there are several limits for 800mm pipes during the construction of pipe-roof jacking.

Installation of Relay Well. In long distance pipe-roof engineering, the relay well is usually used in the pipe jacking. The clearance diameter is about 490mm in the steel relay well with the diameter of 970mm, and it is barely feasible for engineers to go through. While the clearance diameter is only 320mm when the pipe diameter is 800mm, it is almost impossible to go through. Once the shield machine system fails, engineers can't go in for maintenance, and the construction risk is large.

Construction Efficiency. The cross section size of available spacing in the steel pipes under different diameters is shown in Figure 4. The passage height is only 625mm in 800mm steel pipe, it is relatively hard for engineer to work long hours in the pipe, so the work efficiency is low and the construction quality is difficult to guarantee. While the passage height increases to 758mm in 970mm steel pipe, then the work condition is significantly improved, it has tremendous opportunities for the construction quality.



a) pipe diameter of 970mm b) pipe diameter of 800mm

Fig.4. Cross section of available spacing in pipes under different diameters

Conclusions

Based on a pipe-roof engineering, the 2-D numerical analysis model has been built. Through the contrast of ground settlement and the analysis of construction feasibility with different pipe diameter, the following conclusions can be drawn.

The pipe-roof technology with the diameter of 800mm or 970mm can both meet the engineering requirements, and the maximum value of surface settlement with 970mm pipes deduces by about 20% than that of 800mm pipes. So, the pipe-roof with diameter of 970mm is preferred.

From the aspect of construction feasibility, the pipe-roof with diameter of 970mm also has comparative advantage for that there are several construction limits for 800mm pipes during the pipe jacking. Considering that the larger diameter pipe jacking machine, the greater the effect of disturbance on the surrounding ground, the pipe diameter of 970mm is the optimal recommended diameter for practical operation in pipe-roof engineering.

Acknowledgements

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