Reflections of Advanced Support of Leading Pipe–Shed in Portal Section of Loess Tunnel

Zhongming SU, Jugong ZHANG

Shanxi Transportation Research Institute, Key Laboratory of Highway Construction &Maintenance Technology in Loess Region, Ministry of Transport, Taiyuan,030006,china

email:375216207@qq.com，email:40798108@qq.com

Keywords: Loess Tunnel; Leading pipe –Shed; Grouting; Systematic Bolt; Load Sharing Ratio

Abstract. Currently, advanced support technology of leading pipe –shed is often used in the excavation of the portal section, but the design parameters of leading pipe –shed and the support structure haven't yet form a unified standard. The author analyzes its force theory and design parameters. Combined with the effects of advanced support, the paper raises several issues for further research, taking the role of scaffolding into account.

Introduction

In the construction of portal section of loess tunnel, measures of Leading Pipe–Shed and grouting are often combined to be used[1][2]. Method of Leading Pipe–Shed is an important auxiliary method in the construction of shallow buried tunnel, which can avoid the local collapse because of loose surrounding rock and effectively limit surface subsidence. Practice shows that adopting the Leading Pipe–Shed can effectively reinforce the unfavorable geological conditions and reduce the destruction of vegetation, which is favorable to the construction and operation of the tunnel[3][4].

Mechanical principle of Leading Pipe–Shed

Guiding umbrella arch should be constructed before the construction of Leading Pipe–Shed, which can play a guiding role on the one hand and play a role of supporting the Leading Pipe–Shed and improve its mechanical state on the other hand. After the construction of guiding umbrella arch and its concrete strength reaching to the designed requirements, the Leading Pipe–Shed can be constructed, then grouting technology can be operated [5].

Two aspects of the conditions must be available so that Leading Pipe–Shed can form a "shed". The first condition is that the soft soil between the steel tube can form the bearing arch and the second condition is that the bar structure should be sufficient to spread or transfer the pressure of surrounding rock.

When the portal section is excavated, one end of Leading Pipe–Shed is supported by the Guiding umbrella arch and the other end is constrained by the surrounding rock, so its mechanical state is similar to the simply supported beam.

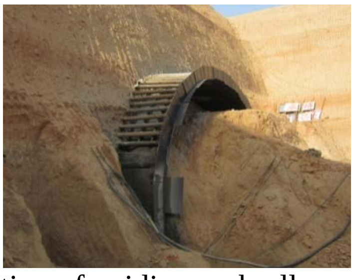

Fig.1 Construction of guiding umbrella arch in loess tunnel

Design of Leading Pipe–Shed

Leading Pipe–Shed generally can be formed by the galvanized seamless steel pipe, of which the thickness of is 6-8 mm and the diameter is 108 mm. The Leading Pipe–Shed should be constructed outside the contour of the tunnel excavation, of which the length is in general 10-30 m and the ring spacing is 0.4 m. The hole distribution of Leading Pipe–Shed is shown in Fig.2

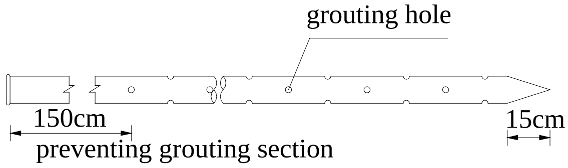

Fig.2 hole distribution of Leading Pipe–Shed

The structural properties of the loess surrounding rock will be destroyed after the disturbance, so the strength of loess will be decreased significantly and increase the pressure of surrounding rock. The Pre-constructed steel reinforcement cage will be put into the Leading Pipe-Shed in the design so as to improve the rigidity of Leading Pipe-Shed, and increase its bending resistance.

The Pre-constructed steel reinforcement cage is formed by 3~4 ribbed steel bar, of which the diameter is 16~22 mm, and fixed ring is welded every 2~3meters.

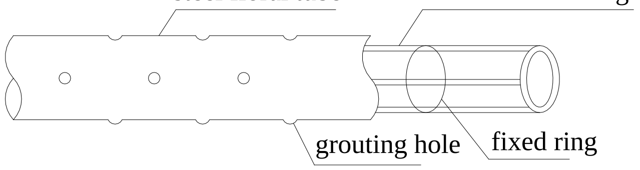

Fig.3 The steel reinforcement cage fixed in the steel tube

Grouting and excavation in portal section of the tunnel

Chen Zhimin, et al [6] analyzed and compared the shear strength index of loess before and after grouting, and did experiments on the change law of the grouting strength of the saturated loess, which indicated that cement and sodium silicate grouting in loess or saturated loess can improve the soil compactness and significantly increase the soil shear strength.

Effect of strengthening the surrounding rock by the Leading Pipe-Shed can be considered by the equivalent method in the numerical simulation, and it can be fulfilled by improving the mechanical parameters. The parameters of grouting soil can be determined according to the experimental data. The grouting calculation model can be shown in Fig.4.

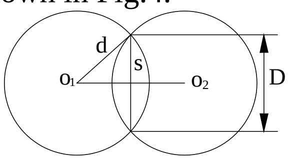

Fig.4 Grouting calculation model of single Leading Pipe-Shed

$$d = \sqrt{\frac{Q}{\pi L n \alpha \beta}} \tag{1}$$

$$D = 2\sqrt{d^2 - \left(\frac{s}{2}\right)^2} \tag{2}$$

$$E = E_0 + \frac{S_g}{S_c} \cdot E_g \tag{3}$$

Where Q is the grouting volume for a single hole, L is the grouting length, n is formation porosity, α is the effective grouting factor, β is the grouting loss factor, d is the grouting diffusion radius, s is the space between the two adjacent grouting holes(m), E is the equivalent soil elastic modulus(GPa), E_g is the elastic modulus of Leading Pipe–Shed(GPa), S_g is the equivalent area of Leading Pipe–Shed support(m^2), S_c is the crossing section of Leading Pipe–Shed support(m^2).

In portal section under the support of Leading Pipe–Shed, the tunnel is excavated still by the method of "ring excavation reserved core soil", and the primary support is formed by I20a shaped steel arch, steel mesh, mortar bolt and shotcrete. In general, the length of the mortar bolt is 3 m and the ring and longitudinal net space is 1 m.

Fig.5 Excavation method in portal section supported by leading pipe-shed in loess tunnel

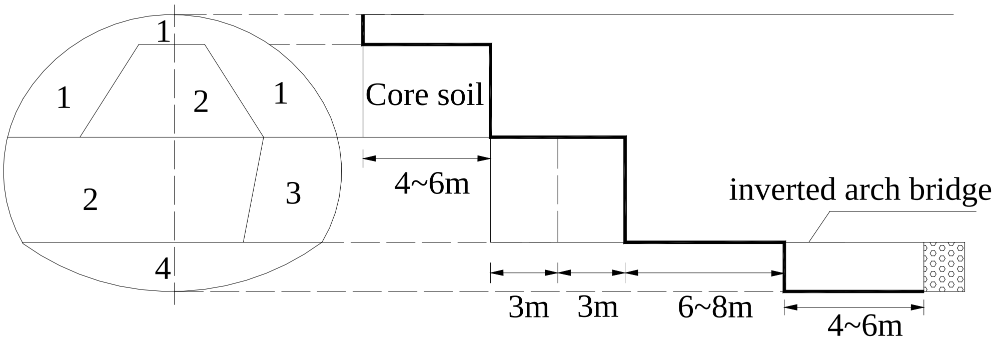

Fig.6 Schemes of "ring excavation reserved core soil"

Several points of understanding and reflection

In the poor performance of the loess surrounding rock, the leading pipe-shed hole is bound to shrink, and may even appear collapse phenomenon. At the same time, it is difficult to insert the steel tube to the designed place. So how to insert the steel tube to the designed place must be considered in the projects practices.

Setting angle1°~3° is often adopted in the design so as to prevent the support invasion. And the insertion of the steel tube destroys the soil structural properties. How to prevent the soil collapse at the bottom of leading pipe-shed still needs to be further discussed.

Grouting significantly improves the soil compactness and shear strength. The mechanical characteristic of systematic bolt in the position of ring arch is different from that in the general tunnel position. Whether the systematic bolt in the portal section can be cancelled still needs lots of field experiments to analyze and illustrate.

Leading Pipe–Shed after grouting will share part of the surrounding rock pressure, so the mechanical characteristic of primary support will be different from that in the position without Leading Pipe–Shed, then the secondary lining will also be different[7][8]. Whether the design parameters of primary support and secondary lining can be weakened will need to be further studied. Whether the shaped steel arch can be substituted for Grid steel arch will also requires lots of illustration.

Concluding remarks

Based on the analysis of mechanical principle &design parameters of Leading Pipe–Shed and the consideration of the role of scaffolding, several problems are put forward which need to be further studied, combined with the understanding of the support effect of Leading Pipe–Shed in loess tunnel.

(1)The designed length of Leading Pipe–Shed in loess tunnel is longer. In engineering practices we must give full consideration to how to make the Leading Pipe–Shed into the place, due to the lower strength of loess surrounding rock.

(2)The soil in the outer contour of the tunnel excavation at the bottom of Leading Pipe–Shed is very likely to collapse during the excavation. How to consider the impact of this part of the soil on the structure and how to prevent the collapse still need to be further studied.

(3)The mechanical characteristics of systematic bolt in the position of arch ring in loess tunnel are still not clear recently, whether it can be cancelled still needs theoretical analysis and lots of field experiments to illustrate.

(4)Whether the grid arch can be used in the primary support in the position of Leading Pipe–Shed and Whether the thickness of secondary lining can appropriately be reduced to a thinner value still need to be further studied .The load sharing ratio of primary support and secondary lining in the position of Leading Pipe–Shed still needs to be further demonstrated.

Acknowledgement

In the process of writing, the paper has been financially sponsored by the application basic research project of Ministry of transportation (NO:2014319771190). Many thanks to the item.

References

[1] Wang Xiaozhou. Construction technology of loess tunnel with large section [M].Beijing: China Railway Publishing House,2009.

[2] Gao Yulan, Zhao Duijia,Su Zhongming. Loess tunnel engineering with small interval in shallow buried places [M]. Beijing: China Communications Press, 2012.

[3] Gu Tianfeng, Sun Zhongdi,Luo Fengtao,et al. Experimental study on grouting filling material of cement& loess[J]. Journal of Engineering Geology,2014,22(1),98-105.

[4] Huo Runke,Wang Yanbo,Song Zhanping,et al. Analysis of performance of primary support in loess tunnel[J]. Rock and soil mechanics,2009,30(S1),287-290.

[5] Guo Jun, Wang Mingnian,Tan Zhongsheng,et al. Study on the mechanical characteristic of systematic bolt in loess tunnel with large span in shallow buried places[J]. Rock and soil mechanics,2010,31(3),870-874.

[6] Chen Zhimin, Zhao Dean,Li Shuangyang,et al. Effect evaluation of cement and sodium silicate grouting in Loess and saturated loess[J].Journal of Lanzhou Jiaotong University (Science Edition), 2004,23(6),48-51.

[7] Li Pengfei,Zhang Dingli,Zhao Yong,et al. Study on the mechanical characteristic of secondary lining in loess tunnel with large cross section[J].Journal of rock mechanics and Engineering,2010,29(8),1690-1696.

[8] Mi Huijie. Field test analysis of load sharing ratio of primary support and secondary lining in loess tunnel [J]. Highway transportation science and Technology (Application Technology Edition) ,2013,(8),158-160.