Academic Journal of Science and Technology
ISSN: 2771-3032 | Vol. 11, No. 1, 2024

Study on Grouting Repair and Reinforcement Technology of soft Foundation of large diameter Highway Tunnel

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Abstract: Taking the uneven settlement of the foundation of a two-way eight-lane large diameter highway tunnel as the engineering background, the joint grouting reinforcement technology of miniature steel pipe pile and steel sleeve valve pipe is put forward. based on the field measured settlement data and foundation core samples, the effectiveness of repair and reinforcement is analyzed. The research results show that the combined grouting of miniature steel pipe pile and steel sleeve valve pipe can effectively control the settlement of tunnel foundation, and significantly improve the RQD (Rock Quality Designation) value of tunnel foundation, which provides technical reference and basis for the construction of similar projects.

Keywords: Highway tunnel; foundation; grouting; steel pipe pile; steel sleeve valve pipe; ROD.

1. Introduction

Uneven settlement of tunnel foundation is a common engineering geological problem, which may cause a series of serious hazards, including but not limited to the following four points.1. Tunnel structure damage: uneven settlement of tunnel foundation may lead to distortion and deformation of tunnel structure, thus affecting the stability and safety of the tunnel. Serious settlement may lead to the rupture and damage of tunnel structure, and even lead to catastrophic accidents such as tunnel collapse [1-3]. 2. Hidden danger of traffic safety: uneven settlement of tunnel foundation may lead to cracks, potholes and other defects on the tunnel road surface, affecting the traffic safety of vehicles. In addition, the settlement may lead to the height difference inside and outside the tunnel, affecting the entry and exit and running of vehicles. 3. The durability of tunnel structure is reduced: the uneven settlement of tunnel foundation may lead to the stress concentration of tunnel structure and accelerate the fatigue and aging of tunnel structure. This will affect the service life and maintenance cost of the tunnel [4]. 4. The project cost increases: the uneven settlement of the tunnel foundation requires foundation reinforcement and repair, which will increase the project cost. In addition, the damage of tunnel structure caused by uneven settlement of foundation may need large-scale repair and reconstruction, which further increases the cost of the project. 5. Social and economic losses: uneven settlement of tunnel foundation may lead to traffic interruption, production stagnation and other problems, thus affecting the normal operation of social economy. Serious settlement may lead to damage to public facilities and infrastructure, resulting in huge social and economic losses.

Therefore, the uneven settlement of tunnel foundation needs to be paid enough attention, and effective prevention and control measures should be taken to ensure the safety, stability and long-term use of the tunnel. In this paper, according to the research background of uneven settlement of the foundation of a two-way eight-lane large diameter highway tunnel, the engineering geological conditions of the site are analyzed, and the repair and reinforcement technology of combined grouting of miniature steel pipe pile and steel sleeve valve pipe is put forward. it provides a reference for solving similar engineering problems.

2. General Situation of Project

Double-hole two-way eight-lane main road tunnel is arranged in the middle of the tunnel, and double-hole two-way four-lane auxiliary road tunnel is arranged on both sides. The length of the left and right holes of the main road tunnel is 4048.5 meters, the length of the left and right holes of the auxiliary road tunnel is 4093 meters, and the length of the four lines of the tunnel is 4070.75 meters. The cross section is shown in figure 1 below. The entrance end is 145 meters of open-cut tunnel and the average length of 303 meters of shallow buried section, the strata are mainly slope silty clay, fully weathered and sand-like strongly weathered granite (tuff lava) strata. The tunnel basement is mainly located in fully weathered and sandy strongly weathered tuff lava layer.

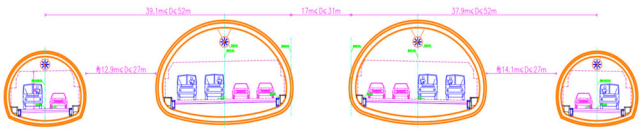

Figure 1. Tunnel section view

The construction unit monitored and found that there are more than 30 longitudinal cracks in the arch roof of the open tunnel section and the shallow buried section, and the largest crack in the second lining is located at the arch waist of the shallow buried section of the right main tunnel, which is as long as 48m. Through the on-site inspection of the inspection unit, the main defects of the tunnel are found as follows: 85 transverse cracks in the second lining concrete, 73 longitudinal cracks in the second lining concrete, 16 oblique cracks in the second lining concrete and 2 network cracks in the second lining concrete. There are 36 longitudinal cracks in the filling layer of the inverted arch of the tunnel, with the crack length 5m - 140m and the crack width 1m - 42 mm. Verified by the inverted arch slotting, the width of the crack

is adjusted for slotting, which reveals that there are penetrating cracks in the widest part of the inverted arch, and there is no obvious deformation of the steel bar, as shown in figure 2 below.

Figure 2. Through-crack slotting diagram

3. Engineering Geological Conditions

According to the strata and detailed exploration data revealed by on-site drilling, the shallow buried section of the entrance section of the tunnel is located in the area of lithology change, the upper part of the tunnel site area is Quaternary residual alluvial layer, and the underlying bedrock are tuff lava of Jurassic formation, late granite and their weathering layers. the characteristics of each rock and soil layer are complex, which mainly include the following soil layers: cultivated soil with a thickness of 0mm and 0.30m. There are more than ten kinds of soil layers, such as 1.40-12.30m silty clay, 5.30m-6.10m tuff lava residual clayey soil, 0.50m-15.70m residual clayey soil, 6.90m-10.20m fully weathered tuff lava, 0.20m- 2.30m fully weathered granite, 13.8m-15.70m sandy strongly weathered tuff lava, etc. Complex stratum is one of the reasons for uneven settlement of tunnel.

According to the investigation, in the vicinity of the prospecting site, there are underground buried objects such as power pipelines and tombs and tunnel construction for drainage and irrigation operations; in the bedrock revealed by the survey, except for the existence of fragments of strongly weathered rock residues, medium to slightly weathered rock residues (solitary rocks) and dense zones of joints and fissures, caves, weak strata and empty surfaces are not revealed. Due to the complex hydrogeological conditions of the proposed engineering site, surface cracking and ground collapse have occurred in tunnel construction activities, which further develop or induce landslides or collapses.

After the arch foot grouting was carried out in the initial stage, the lining deformation and cracks continued to develop. The traditional single scheme of grouting reinforcement can not effectively control the deformation of the tunnel, so it is necessary not only to improve the discontinuity of the soil layer of the tunnel foundation, but also to improve the structural integrity of the tunnel and the foundation. finally, the combined grouting technology of micro-pile and steel sleeve valve pipe is considered to repair and strengthen the tunnel foundation.

4. Repairing and Strengthening Technology of Foundation by grouting

4.1 Steel sleeve valve pipe grouting in inverted arch foundation

The bottom of the tunnel is mainly located on residual alluvial soil, fully weathered and sandy strongly weathered rock, and its structure is loose and easy to soften in the presence of water. There is a gravel cushion with thickness of 60cm at the bottom of open-cut tunnel section, which is a weak channel for water storage and confluence. Considering that the gravel cushion is rich in water, as shown in figure 3 below, the effect of ordinary grouting is poor, and the problem of serial grouting is serious under the condition of dense grouting holes. in order to ensure the grouting effect of crushed stone cushion, steel sleeve valve pipe grouting is used. The grouting schematic diagram of steel sleeve valve pipe is shown in figure 4.

Figure 3. Actual picture of Water-rich macadam cushion

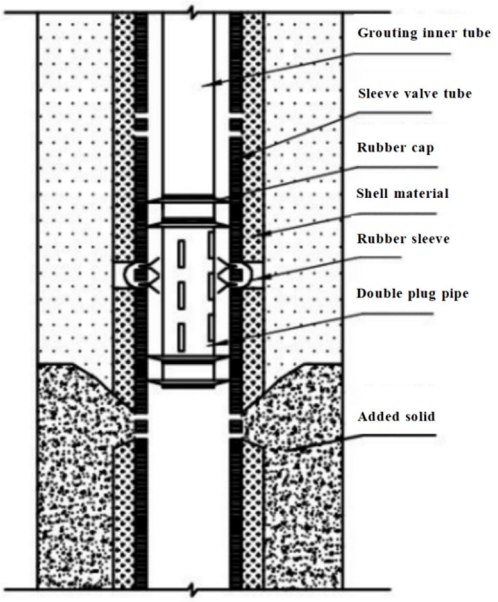

Figure 4. Principle diagram of Grouting for steel sleeve valve pipe

The construction process of steel sleeve valve pipe is shown in Figure 5.

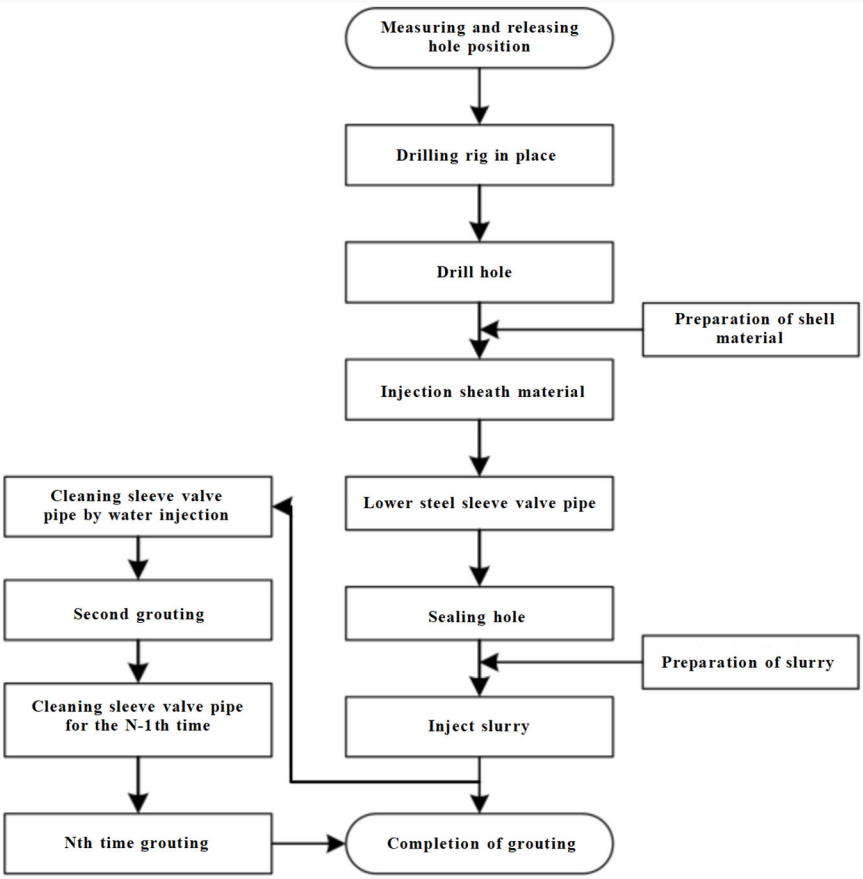

Figure 5. Steel sleeve valve pipe grouting construction process flow chart

The construction sequence of steel sleeve valve pipe reinforcement of inverted arch foundation is shown in Figure 6, which is divided into the following two stages,

(1) Segment division of grouting unit. Considering all factors, three rows of grouting holes are used to divide 40m into one grouting unit. Inject into the front and back rows first, and last in the middle row. The grouting formation is only gravel cushion.

(2) Grouting sequence within the grouting unit. The grouting process for reinforcing the inverted arch foundation: first gravel formation and then fully weathered granite (first up and then down), jump injection in every hole, first outside then inside, first downstream holes and then upstream holes.

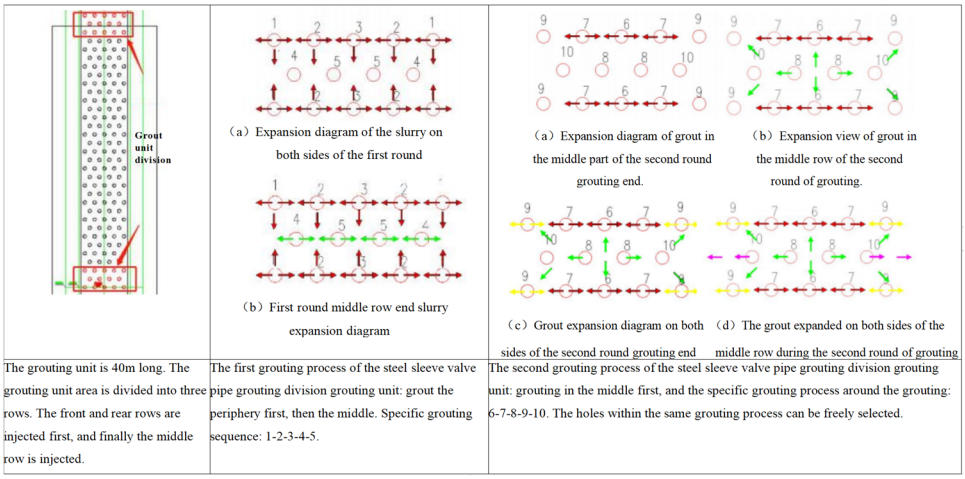

Figure 6. Construction sequence diagram of steel sleeve valve tube reinforcement of inverted arch foundation

4.2 Grouting of micro steel pipe piles at arch feet

The arch foot foundation reinforcement is carried out after the second round of grouting of the steel sleeve valve pipe of the inverted arch foundation in the open tunnel section is completed. The specific construction process is shown in Figure 7.

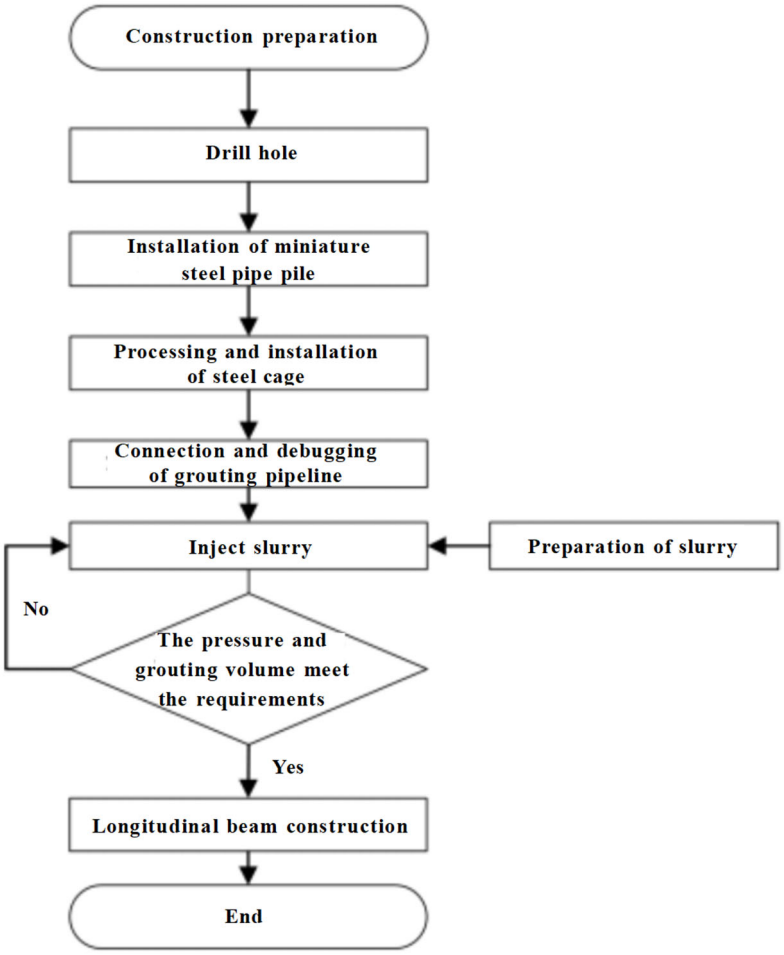

Figure 7. Micro steel pipe pile construction process flow chart

Micro steel pipe piles are made of Φ108×6mm hot-rolled seamless steel pipes, which are processed in steel component processing plants. If the construction is inconvenient, 3m and 6m steel pipes are used. The front end of the steel pipe is in a pointed cone shape, and a Φ6 stiffening hoop is welded on the tail. The structural diagram is shown in Figure 8. 15mm grouting holes are drilled around the pipe wall, with a hole spacing of 15cm and a plum blossom arrangement; a grouting stop section is set 2.0m from the hole mouth, and no grouting holes are set.

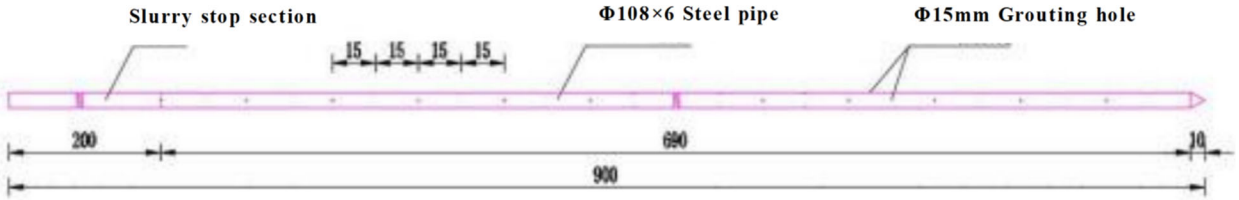

Figure 8. Construction sequence diagram of steel sleeve valve tube reinforcement of inverted arch foundation

The grouting pressure is 1.0-2.0Mpa, and the grouting parameters are adjusted according to field tests. In principle, the grouting sequence follows the principles of "first both sides and then the middle" and "step by step".

4.3 Foundation settlement monitoring and core sample RQD value changes

After the tunnel foundation was jointly grouted with steel sleeve valve pipes and micro-steel pipe piles, and after one month of continuous dynamic data monitoring by the testing unit, the settlement rate of the tunnel foundation and arch feet was significantly alleviated, and both were lower than the design values.

The tunnel foundation and arch foot after grouting were drilled and cored respectively. The average RQD values of the core samples increased by 15% and 12% respectively, as shown in Figure 9, especially the integrity of the water-rich gravel cushion at the bottom. significantly improved. This shows that this combined grouting technology improves the overall structural properties of the tunnel.

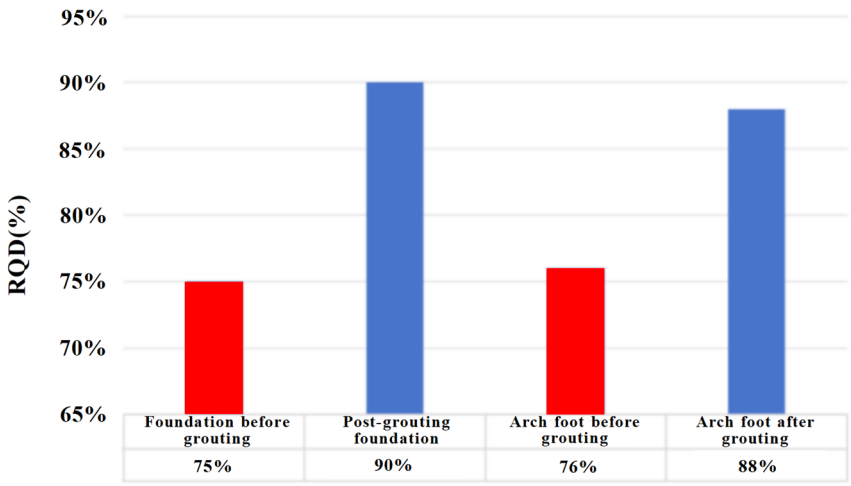

Figure 9. Changes in RQD values of tunnel foundation and arch foot cores before and after grouting

5. Conclusion

In this paper, through the grouting reinforcement and repair of the uneven settlement of the large cross-section highway tunnel, and through the analysis of the on-site settlement and foundation core sampling, the following conclusions are drawn.

(1) the combined grouting technology of miniature steel pipe pile and steel sleeve valve pipe can effectively control the continuous uneven settlement of the tunnel foundation and strengthen the whole structure of the tunnel.

(2) the combined grouting technology of miniature steel pipe pile and steel sleeve valve pipe is effective in strengthening the soft foundation of the tunnel, and significantly improves the RQD value of the tunnel foundation.

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