Application of Advanced Long Pipe Shed Construction Technology in Drift-Rock Mound Tunnel

Gendong Pan[1,a], Kai Xu[2,3,*], Wei Zhang[1,c], Yong Li[1,d], Xiaoyue Kang[2,3,e], Yichun Huang[1,f], Dongxing Liu[2,3,g]

[1]Zhejiang Communications & Investment Transportation Construction Management Co. Ltd. Hangzhou, China
[2]China Merchants Chongqing Communications Research & Design Institute Co. Ltd. Chongqing, China
[3]Highway Tunnel National Engineering Research Center, Chongqing, 400067, China

[a]GendongPan@163.com, [*]xukai@cmhk.com, [c]WeiZhang8492@163.com
[d]YongLi8492@163.com, [e]kangxiaoyue@cmhk.com, [f]731956865@qq.com
[g]2261655762@qq.com

Abstract. Floating rock pile belongs to a special geological type, body stability of tunnel hole had a serious impact, based on the Wolong groove of a tunnel, drift rock pile in high altitude cold and arid regions of engineering characteristics were analyzed, and put forward using advanced and long pipe roof construction technology to carry on the preliminary support, introduces its construction process, to ensure the safety of the floating pile rock tunnel construction, to provide technical reference for tunnel construction problems of the same type.

Keywords: Tunnel engineering; Boulders; Lead long pipe shed

1 Introduction

During the construction of highway tunnel projects, due to the complex geological environment in the tunnel construction area, adverse geological conditions such as fractured rock zones, loose and weak surrounding rocks, shallow burial and partial pressure are often encountered during tunnel excavation and support. Excavation is highly susceptible to damage and disturbance, thereby affecting the stability of the surrounding rock. Therefore, different construction methods should be selected for different geological conditions in tunnel engineering construction.[1-2]

The boulder-rock accumulation body has obvious heterogeneity and anisotropy, which can have serious adverse effects on tunnel construction. In response to the construction problems caused by boulder-rock accumulation geology, a large number of scholars have carried out relevant research. In the context of studying the construction environment of accumulations dominated by silty clay and rich in groundwater, Liu Guoqing [3] introduced the application of long pipe roof construction methods in complex geological environments to ensure the smooth progress of construction. Mean-

H. Bilgin et al. (eds.), *Proceedings of the 2024 6th International Conference on Civil Engineering, Environment Resources and Energy Materials (CCESEM 2024)*, Advances in Engineering Research 253,
https://doi.org/10.2991/978-94-6463-606-2_41

while, weak surrounding rocks are also often encountered during highway tunnel construction, and the use of advanced long pipe roof support construction technology can effectively guarantee the construction quality of tunnel projects [4-6]. Wang Kai [7] introduced the application of long pipe roof advanced support technology under adverse geological conditions. Liu Hesong [8] introduced that during the construction of advanced long pipe roof, problems such as construction disconnection and pipe roof encroachment are prone to occur, which can pose safety hazards to the tunnel. Huang Yongsheng [9] supplemented its scope of adaptation and application while introducing its construction technology.

2 Project Overview

This project is located in Linxia County, Gansu Province and Xunhua County, Qinghai Province, within the mountainous and heavily hilly area, with an altitude ranging from 3000m to 3500m. The total length of the route is 8.12 km. The Wolonggou Tunnel No.1 traverses the border between Gansu and Qinghai provinces. This tunnel is a separated tunnel. Due to the influence of terrain, there is a significant elevation difference between the two provinces, thus a spiral tunnel design is adopted. The total turning angle of the tunnel is nearly 220°, with a minimum curve radius of 700m. It features a concentrated slope rise, resulting in an elevation difference of 58m between the entrance and exit. The right tunnel starts from K6+008 and ends at K8+562.63, with a length of 2554.63m, and adopts a one-way slope of 2.3%; the left tunnel starts from ZK6+062 and ends at ZK8+688, with a length of 2626m, and adopts a one-way slope of +2.2%. The portal at both the entrance and exit adopts an end-wall type. The underlying bedrock in the tunnel site area is mainly composed of boulder rock piles, and unfavorable geological structures such as fault zones can be found in the area.

Located at the transitional zone of the Qinghai-Tibet Plateau, this project faces complex and scattered stratigraphic distributions, well-developed geological structures, and numerous unfavorable geological conditions along the route, as shown in Fig. 1. Moreover, the project route traverses several environmentally sensitive areas, including the Taizishan National Nature Reserve and the headwaters of Sanjiang River source region, necessitating high ecological and environmental protection standards.

Fig. 1. Tectonic denudation alpine landform.

3 Engineering Properties of Boulder Piles

3.1 Formation Mechanism of Boulder Piles

In the intersection of tectonic zones with different geological conditions, boulder piles are formed due to crustal movements that create numerous folds. The rock strata, under compression and stacking, develop relatively well-developed joints and fractures, forming irregular cuboids. These cuboids, under the effects of weathering and peeling, accumulate at the foot of the mountain to form boulder piles [10]. Additionally, the formation of boulder piles is primarily attributed to the fragmentation and uneven weathering of rock masses such as mudstone, schist, and slate, resulting in partially steep slopes with weak lithology and low weathering resistance. During weathering, the slope surface appears stepped or serrated. Due to geological activities such as transportation and erosion, the spatial distribution of boulders is random, and boulder piles tend to accumulate at the slope angles. As shown in Fig. 2, boulders are prone to uneven settlement in the strata. They generally have round or oval shapes and are usually inclined when distributed in the strata. When subjected to external forces, the middle part bears more stress, while the stress on the two sides is smaller due to the smaller stress area. This results in rotation, changing the pores between soil masses, and causing the water and fine sand and gravel in the pores to move, leading to changes in soil structure.

Due to the low strength and irregularity of boulder piles, they pose certain safety hazards to tunnel construction, necessitating corresponding measures to strengthen support.

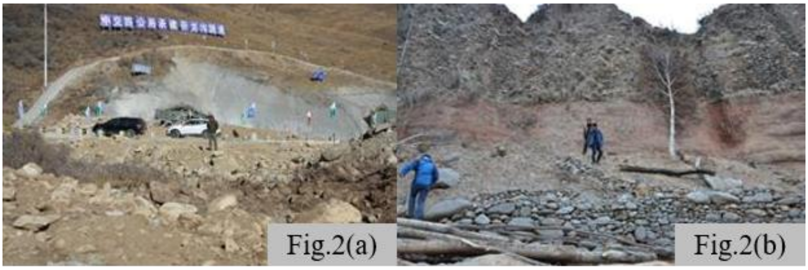

Fig. 2. Field conditions of boulder piles.

3.2 The Impact of Boulder Piles on Tunnel Construction Engineering

According to statistics, from 2013 to 2021, rock pile tunnel collapses have become one of the most common safety accidents in mountain highway tunnel construction in China. Due to the soft and loose nature of the rock piles, rapid deformation often occurs during construction, resulting in significant arch settlement and clearance displacement, making them highly prone to collapse [11]. For example, the collapse of the rock pile at the entrance of the Gao Yang Zhai Tunnel on the Yi Wan Railway caused the tunnel operation to be paralyzed, and the landslide of the right side of the right tunnel exit section of the Si Fang Shi Tunnel on the Ma Liu Wan-Zhaotong section in Yunnan, caused by construction disturbance of the soil, resulted in huge casualties.

At the same time, due to the strong permeability of the rock pile and the frequent presence of water storage layers in the soil, the tunnel grouting and drilling effects are severely affected under the action of moving water and water pressure, which can even lead to tunnel collapses and instability of the initial support. In 2006, the Ma Lu Qing Tunnel of the Yi Wan Railway in China crossed the broken rock pile strata, and the construction environment was accompanied by a large amount of groundwater. The disturbance of the rock mass during the tunnel excavation led to a large-scale water inrush into the tunnel, posing a serious threat to construction safety and tunnel stability.

In addition, due to the random distribution of rock piles, they have obvious non-uniformity and anisotropy, which can also lead to drilling jamming and collapse during tunnel construction. They cannot provide a good support base for anchor rods, resulting in low anchoring capacity, which greatly affects the construction rate of shotcrete support. On the other hand, the rock pile is very sensitive to dynamic loads during tunnel construction. As a poor geological condition, the rock pile is in a very critical balance state. When there is lateral pressure, the tunnel is prone to lateral displacement and distortion, which poses a severe challenge to the smooth construction and safe operation of the tunnel project.

4 Advanced Long Pipe Roof Construction Technology

The advanced long pipe roof construction technology is a tunnel construction method suitable for weak surrounding rocks in buried tunnels. Drawing on the experience of advanced pipe roof support construction technology for weak surrounding rocks both domestically and internationally, and combining the specific geological characteristics and support construction requirements of this project, an advanced long pipe roof construction scheme was adopted for the boulder accumulation rock area of Wolonggou Tunnel No.1.

4.1 The Overall Process of the Advanced Long Pipe Shed Construction

The advanced long pipe shed construction technique can provide primary reinforcement to the strata through pre-support of the pipe shed and grouting for filling and reinforcement. The long pipe shed serves as a pre-support structure that is directly inserted into the strata. Grouting materials are then injected into the surrounding strata through the pipe shed, filling the voids in loose strata and enhancing the overall strength and deformation resistance of the strata. Subsequently, the steel pipes of the pipe shed are connected by welding or mechanical means, forming a continuous support structure that constitutes the second reinforcement system of the tunnel structure. Moreover, the guide wall plays a role in fixing and guiding during construction, ensuring that the pipe shed is accurately installed according to the design direction and position, which further strengthens the stability of the tunnel structure from the perspective of construction precision and stability. In addition, in the later stages of construction, measures such as post-support and lining, drainage and waterproofing, and construction monitoring can continue to ensure the stability and integrity of the tunnel structure, as well as the safety of the construction process.

The fundamental workflow of the advanced long pipe shed construction process, as depicted in Fig. 3, primarily involves establishing the excavation boundary of the side slope based on the design drawings, and applying slope protection with shotcrete. Subsequently, an orientation wall is implemented to serve as a guide and stabilizer for the pipe shed construction. A drilling platform is constructed and a drill rig is installed for the drilling operation, which necessitates cleaning the inner rods, retracting the inner rods, and pulling back the pipe sleeves. The pipe shed is then installed, culminating with the grouting process.

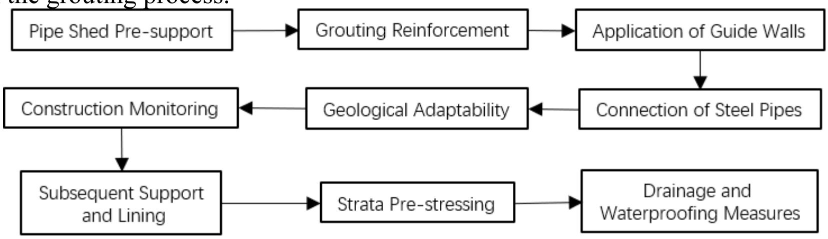

Fig. 3. The overall process of the advanced long pipe shed construction.

4.2 Drilling Construction

For this drilling operation, 140 seamless steel tubes are used as guide pipes with a circumferential spacing of 40 cm. The drill pipes of the hydraulic trolley are 4.3 m and 5.5 m long.

When drilling deep holes, the drill pipes need to be connected using drill pipe connectors, and the material of the connectors should be the same as that of the drill pipes to ensure the overall strength after connection. The schematic diagram is shown in Fig. 4.

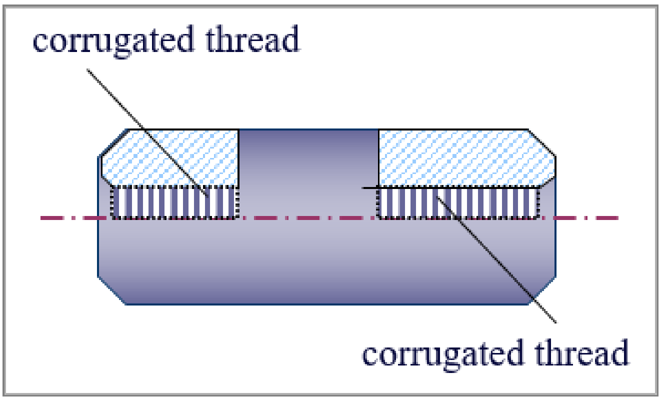

Fig. 4. Schematic diagram of drill pipe connector.

The process flow for deep hole drilling is shown in Fig. 5.

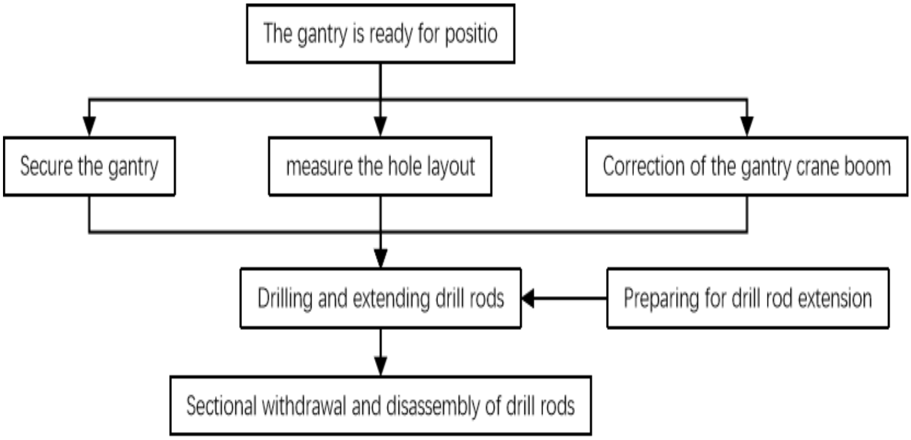

Fig. 5. Flowchart of deep hole drilling construction process.

The key points for deep hole drilling operations are as follows:

(1) Before drilling, the trolley should be driven to the tunnel face for positioning, and the surveyor should stand on the tray of the trolley arm to determine the specific location of the drill hole. To prevent vibration from affecting construction accuracy, the trolley arm must be tightly pressed against the tunnel face during the drilling process.

(2) When the drill starts working, the rotation speed should not be too fast. After drilling to a depth of approximately 20 cm, the speed should be controlled to normal. After the first section of the drill pipe is drilled into the rock, drilling should stop when about 25 cm remains at the tail. Then, the second section of the drill pipe with a connector sleeve installed should be manually loaded into the drill, and the drill should connect the second section with the tail of the first section into one unit.

(3) Since drill pipes may be damaged and become unusable during the drilling process, it is necessary to promptly inspect the overall structure of the drill pipes during construction to check for obvious bending, damage, and whether the central water hole is unobstructed. In case of any of the above situations, immediate replacement is required.

(4) The diameter of the pilot hole should be 15-20 mm larger than the outer diameter of the pipe roof, and the hole depth should be more than 0.5 m longer than the pipe length.

4.3 Process Flow of Pipe Jacking

The process combines the use of large-diameter pilot holes and shed pipe drilling, where the drill's impact and thrust are utilized to jack the shed pipe with a working pipe head along the pilot hole, and the shed pipe is extended section by section until it reaches the bottom of the hole. The process flow is illustrated in Fig. 6.

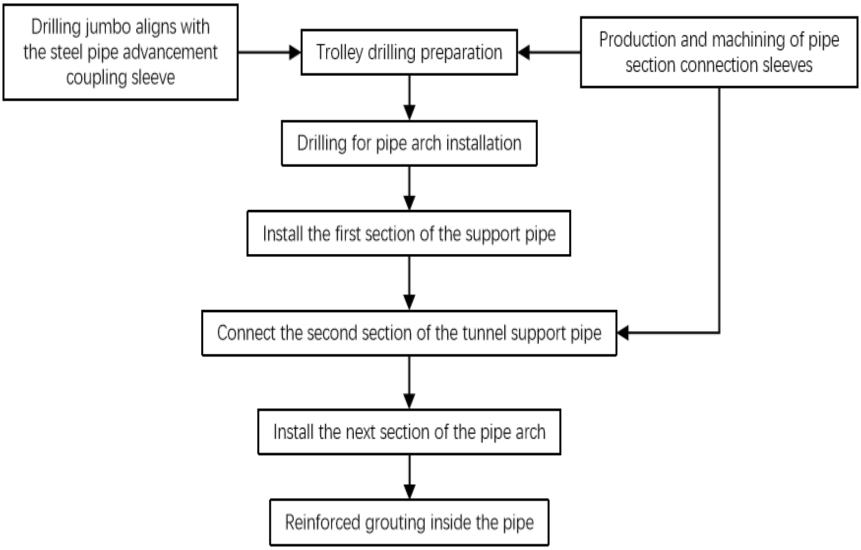

Fig. 6. Flowchart of pipe jacking construction process.

The key points of pipe jacking technology and operation are as follows:

(1)Pipe fitting fabrication: Φ1086 mm hot-rolled seamless steel pipes are adopted, with pipe section lengths of 3 meters and 6 meters. Considering that the left and right tunnels at both the entrance and exit of Wolonggou Tunnel No.1 are 30 meters long, it is necessary to extend the pipe sections. When extending the pipe fittings, the joints of adjacent pipe sections must be staggered front and back to ensure structural stability. Fig. 7 illustrates the schematic diagram of pipe joint couplings.

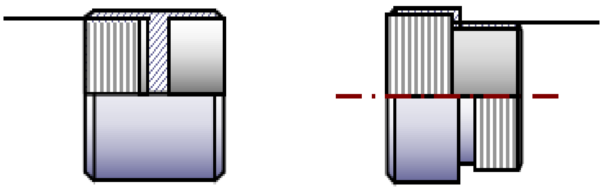

Fig. 7. Schematic diagram of pipe joint couplings.

The construction of long and large pipe sheds adopts a double-arm hydraulic drilling jumbo, in which one large arm uses a Φ120 percussion drill bit to drill pilot holes, as shown in Fig. 8, while the other large arm is used to jack in Φ108 shed pipes. On the jacking arm's rock drill, it is necessary to install a steel pipe jacking coupling sleeve that corresponds to the diameter of the pipe shed, as shown in Fig. 9(a), and replace the large arm with a specially made steel pipe straightener, as shown in Fig. 9(b). After the pilot holes are drilled, the jacking arm is used to perform the jacking operation.

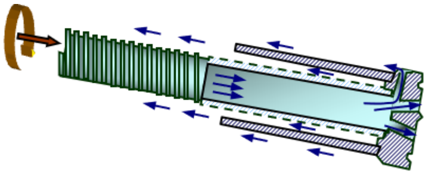

Fig. 8. 120mm diameter percussion drill bit.

Fig.9(a) Fig.9(b)

Fig. 9. Schematic diagrams of pipe shed jacking coupling sleeve and trolley boom straightener. (a) Schematic diagram of jacking coupling sleeve; (b) Schematic diagram of the trolley boom straightener.

(2) Pipe jacking operation: The other boom of the double-arm hydraulic drilling trolley is used to jack in the steel pipe. During operation, the steel pipe should be advanced at a low speed, and the pressure should be controlled at around 1.9 MPa during jacking, with the propelling pressure controlled at around 5 MPa.

(3) Pipe connection: When approximately 30cm of the first steel pipe remains, the boom's jacking coupling sleeve needs to be separated from the steel pipe. The rock drill reverses, and personnel manually connect the steel pipes. The two sections of steel pipe are connected into one unit at the coupling sleeve. The boom is then realigned with the prepared steel pipe, and the rock drill advances the steel pipe at a low speed.

(4) Grouting and consolidation: Efforts should be made to prevent grout bleeding, and the process should be stopped immediately if it occurs. At the same time, ensure even grouting. A hammer can be used to tap the steel pipe; if a clear ringing sound is heard, it indicates the presence of voids and that the steel pipe is not fully grouted.

(5) Reinforcement of pipe shed: Before reinforcement, the pipes should be cleaned to enhance the stiffness and strength of the pipe shed. Reinforcement method: Under normal conditions, cement concrete is injected into the steel pipe to form a cement-concrete-filled steel pipe. In cases of collapse, surrounding rock damage, or similar conditions, a Φ20 steel cage should first be placed inside the steel pipe, and then grouting is performed inside the pipe to form a concrete-filled steel pipe.

5 Conclusion

(1) The distribution of boulder-rock piles is random, and when subjected to external forces, different locations cannot bear forces evenly, often causing construction problems such as drill jamming, hole collapse, insufficient anchoring force, and water and sand gushing in tunnels.

(2) Long advance pipe roof support plays a positive role in the construction of tunnel projects with boulder-rock piles. It can effectively prevent collapse during tunnel face excavation, form a stable composite consolidated body after grouting, and does not require particularly large construction machinery and equipment, demonstrating good technical and economic performance. At the same time, it is necessary to control every construction step to ensure the quality of construction during the process.

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