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Research on the Hydraulic Tunnel Construction Technology in Adverse Geological Environment

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Abstract: *The construction of hydraulic tunnels under unfavorable special bad geological conditions is difficult, as accidents such as collapse, roof fall, water inrush, mud inrush, etc. may occur and cause serious consequences, with high construction risk. The use of a reasonable construction scheme can reduce the probability of accidents and ensure the safety of construction. Therefore, the construction technology of the section with water inrush and collapse has been researched. First, the tunnel is dredged and the tunnel face is closed, and the construction is carried out using big pipe shed, supplemented with pre-grouting small pipe, followed by the second concrete in time to ensure the construction Safety.*

Keywords: *hydraulic tunnel; gushing water; collapse; technical scheme; construction of big pipe shed*

1. Geological situation and overview of the project

The total length between the 44# construction adit and the 45# construction adit of the main tunnel of a Yellow River diversion project[1~2] is 800m, and the longitudinal slope i=1/3000. Geology of the project: the ground elevation is 1018~1022m, and the buried depth of the tunnel bottom is 57~61m. The tunnel body runs through the Quaternary Holocene mixed soil and bad-gradation sand lenticle. The result of drilling holes shows that the groundwater level in this section is above the bottom of the tunnel. The surrounding rock of this tunnel section is a loose layer, with poor stability, and the surrounding rock category is Class V. The groundwater harms the stability of surrounding rock, as there is the possibility of water inrush and sand inrush. There is a river that flows continuously throughout the year above the roof of the tunnel section, which is regarded as the mother river by the locals. Therefore, it is very necessary to take relevant measures to avoid accidents in the river.

Construction Status: Due to the large water inrush in the tunnel face during the construction last year, the surrounding rock of the tunnel body was mainly sandy gravel. In addition, during the construction of the 0+305~0+310 section, the top collapsed seriously. After the construction for more than half a year by adopting large pipe sheds and centralized drainage measures, the construction of the tunnel face has reached 0+360.

However, due to the large water inrush, poor lithology, difficulties in construction, the construction of the tunnel has been suspended since the end of last year; After the improvement of construction measures by using three large-scale water pumps to centrally drain the accumulated water in the tunnel, the water level has dropped to the face of the tunnel. The 0+320~+360 section of the tunnel was dredged (silt and collapse bodies are more than 2m thick), and the side walls and vaults of this section were reinforced by grouting. After that, the tunnel face was dredged again, and the invaded area was expanded and excavated to prepare for the construction of the large pipe shed; in the process of dredging the tunnel face, the arch frame of the tunnel face and the vault collapsed, and a large amount of sand and stones gushed from the vault and filled the face of the tunnel.

Based on the conditions of the surrounding rock of the tunnel face, it is difficult to run through the collapsed section of the tunnel with conventional construction methods[3~4], such as large pipe sheds according to the previously reported construction plan. In order to ensure the safety of the construction of the collapsed section and the orderly development of work, the treatment plan was re-developed and optimized.

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2. Treatment scheme

Based on site survey and analysis of a large amount of long-term drainage in the tunnel, the current impact area of the tunnel is estimated to be about 30m, and the landslide sediment and stones are all accumulated in the tunnel and above the top of the tunnel, leaving a cavity above the slumped body. The rock layer is still slowly collapsing until the loose body fills the cavity area. According to the current situation of the tunnel face in the collapsed section, if the large pipe shed is to be adopted[5], the tunnel face must first be closed to form a grouting wall; and then a workshop for the big pipe shed must be built. The main measures are as follows:

2.1 Dredging in tunnel and construction of closing tunnel face

After the collapse, the tunnel face is mainly filled with sand and stones, and there is a large water flow. It is difficult to close the current tunnel face by directly hanging the net and spraying concrete and guarantee the firmness of the tunnel face, because there is the possibility of silt and rock gushing out at any time; therefore, it is recommended to properly remove the slumped body first, and then close the entire section of the tunnel face with C20 concrete at the 0+355 mileage position. If conditions permit, the distance between the location of the blocking wall and the tunnel face should not be greater than 10m.

2.2 The production of a workshop

For grouting of sand and gravel (this work has been completed at present), φ42 steel pipe was used for grouting. The grouting hole was set 1m longitudinally along the axis of the hole, and the circumferential spacing is 1×1m, with plum blossom type layout. The tube length is 3m/piece. The two-liquid grouting method is adopted. The ratio of the two-liquid slurry is as follows: the water-cement ratio of cement slurry is 1:1, the volume ratio of cement slurry and water glass is 1:1 or 1:0.5, and the modulus of water glass is 2.4. The Baume degree of the slurry is 35Be°, and the grouting pressure is not less than 0.2mp. The layout of grouting construction is shown in Figure 1.

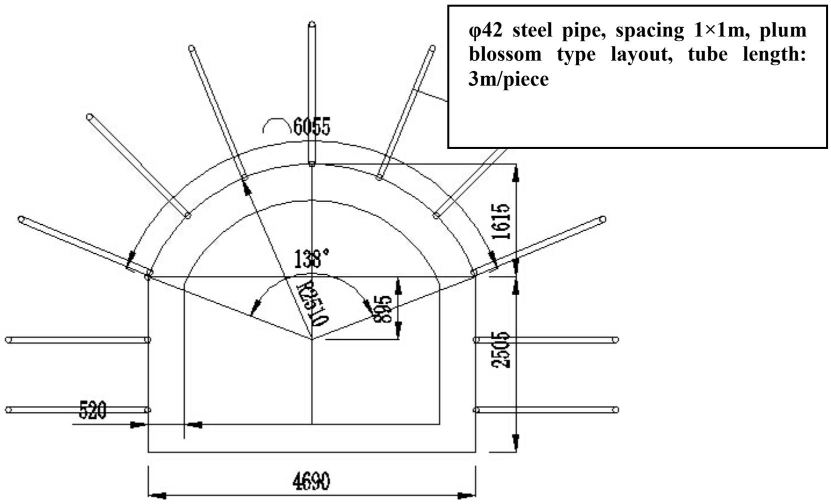

Figure 1: Grouting reinforcement layout

Before the construction of the large pipe shed, in order to prevent the large pipe shed from invading the second lining concrete, the workshop required for the construction of the large pipe shed must be first built. The construction of the workshop was to remove the supporting arch frame, concrete steel mesh and small ducts and the original large pipe shed at the position of the concrete stop wall, and use the frame to support. The length of the workshop is not less than 10m, with an expansion of 1.5m in the radial direction (preparation for the radial expansion of the subsequent excavation section by 1m) to provide the required space for the construction. The steel arch headroom of the workshop is increased according to actual needs, and the same level of concrete was used for backfilling and compacting during the construction of the second lining concrete in the workshop.

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2.3 Construction of φ108 advanced long and large pipe shed

After the construction of the workshop was completed, two steel arches were erected between the upper and lower arches at the end of the supported workroom, and a guide tube was installed on the steel arch with an external angle of 2°~3°, and then the advance φ108 large pipe shed (as shown in Figures 2 and 3) was constructed in the working room within the range of 145° of the vault of the tunnel body through the guide pipe. The pipe shed should be constructed by the professional team and constructed by starting with the arch frame that has been initially supported. The longitudinal length of the pipe shed is 30m/ring, the wall thickness of the pipe is 6mm, and the circumferential spacing is 20cm. The construction adopts the method of one-time transfer with the pipe. The pipe head is equipped with a percussion bit and a supporting impactor. The drilling tool is a combined cutting tool, and the one-time drilling depth is 30m.

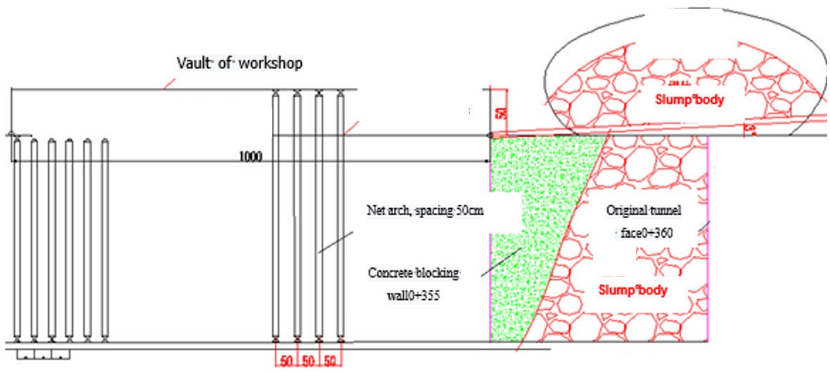

Figure2: Longitudinal section support for advanced large pipe shed construction

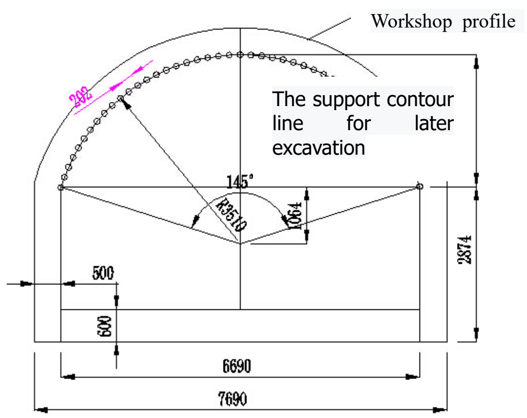

Figure 3: Cross section of support for expanded excavation

2.4 Construction and grouting of large pipe shed

The male and female wires were used to connect the long and large pipe shed, the grouting hole was cut on the pipe body, with a diameter of 5mm, and the holes were arranged with the plum blossom pattern and an eye distance of 50×50cm. The two-fluid grouting (water glass-cement) was injected into the large pipe shed to consolidate the gap between the sand and gravel layer and the pipe shed. The curtain grouting was used to achieve the effect of blocking the permeable layer and filling the large pipe shed. The strength was increased to ensure the construction quality of the large pipe shed. The two-liquid slurry is cement slurry, the water-cement ratio is 1:1, and the volume ratio of water glass to cement slurry is 1:0.5 (or 1:1). The grout with a modulus of 2.4 and 35be ° was selected for water glass, and the grouting pressure was greater than 0.2MPa.

2.5 Support measures for excavation

Before the excavation, the concrete blocking wall and slump body were removed first, and the originally deformed arches and reinforced concrete sections 0+355~+360 were removed one by one,

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and the support was provided before re-excavating the tunnel body.

(1) Due to the large water inrush on the tunnel face, three large water pumps must be used to drain the tunnel face. According to the original design, the width of the cave body was relatively narrow. After the pumps were placed on the face of the tunnel, other equipment can't carry out normal tunneling construction. Therefore, in order to ensure that the working face can be drained and the tunneling will not be affected, the excavation width of the 0+360~+380 section (length 20m) is radially widened by 1m, and the vault is recommended to be increased by 1m at the same time so that the installation of the air duct will not affect the normal construction of the mechanical equipment in the tunnel.

(2) Due to the special geological conditions in this section, I-steel arches were arranged to support the tunnel at 0.5m~0.8/th; the steel bars in the longitudinal direction are φ20 steel bars, and the circumferential spacing is 100cm. A mesh was set on the full section, with a grid spacing of Φ8@20×20cm, and the thickness of the shotcrete was strengthened to 20cm.

(3) When installing the steel arch frame, lock-foot anchor rods or anchor pipes were added at the joints of the steel frame and the feet of the steel frame, with 4 to 8 anchor pipes arranged on each side. The length of the anchor rod or the anchor pipe is 2.5m, and φ25 steel bar or φ42 pipe was used and welded firmly with the steel frame. If the anchor pipe was used for cement or water glass double-liquid slurry grouting, the anchor pipe should be arranged at a depression angle of 30-45°.

(4) At the bottom of the tunnel, a steel frame of the bottom arch was added for each arch of the tunnel bottom for full enclosing. At the same time, the bottom arch was poured with 20cm thick C15 concrete to enhance the strength, so that the vehicle can run on the bottom plate in a short time and the excavation and support cycle time can be shortened. The material of the bottom arch is I-steel of the same type as the steel arch, and it is welded firmly with the side wall steel arch.

(5) Due to the long pipe shed, the height difference between the pipe shed and the roof of the tunnel will become larger and larger. If the construction is carried out by 3° extrapolation, the height difference between the 30m pipe end and the designed vault will reach about two meters. During the excavation process, the sediment below the pipe roof and above the roof of the tunnel will all collapse to form a collapse cavity. The cavity above the vault and the pipe roof was backfilled with wood (or perlite powder) and sprayed concrete.

3. Conclusion

The construction of hydraulic tunnels under unfavorable special bad geological conditions is difficult, as accidents such as collapse, roof fall, water inrush, mud inrush, etc. may occur and cause serious consequences, with high construction risk. The use of a reasonable construction scheme can reduce the probability of accidents and ensure the safety of construction. Therefore, the construction technology of the section with water inrush and collapse has been researched. First, the tunnel is dredged and the tunnel face is closed, and the construction is carried out using big pipe shed, supplemented with pre-grouting small pipe, followed by the second concrete in time to ensure construction Safety. By adopting the optimized scheme, the tunnel section with water inrush collapse was successfully constructed and the expected goal was achieved, which can provide a reference for the construction of similar hydraulic tunnels.

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