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Application Strategies of Shotcrete Anchor Support Technology in Highway Bridge and Tunnel Engineering

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Abstract: This article analyzes the application strategies of shotcrete anchor support technology using a highway bridge-tunnel construction project as an example. The article covers various strategies, including support plan formulation, mortar shotcrete anchor construction, grid steel frame construction, steel mesh construction, and concrete support construction. This analysis aims to provide a guideline for those interested in applying this technology and improving the quality and safety of highway bridges and tunnels construction.

Keywords: Highway bridge engineering; Tunnel construction; Shotcrete support; Support plan; Support construction

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1. Foreword

In the tunnel construction of modern highway and bridge projects, shotcrete anchor support technology is the most critical construction technology. Based on this, the construction unit should adopt reasonable strategies to carry out shotcrete support construction based on the specific project profile and its engineering design standards. In this way, the application advantages of this type of technology can be maximized to meet the actual construction needs of highway, bridge, and tunnel projects, and the overall construction quality and safety can be well controlled [1].

2. Project overview

The total length of a highway bridge-tunnel studied in this paper is 3856 m. The overall road section is linear, with slopes of 9.7% and 14.6%, respectively. Among them, 255 m of surrounding rock is grade II, and 2035 m of surrounding rock is grade III. During the excavation of the highway bridge-tunnel, the surrounding rocks on the uphill and downhill positions are easily disturbed. They will likely lead to collapse accidents if they cannot be well supported. This kind of situation will not only have a great adverse impact on the construction progress and construction quality but also pose high safety risks. In serious cases, it may even lead to safety

accidents such as casualties and damage to construction equipment, thus causing a greater degree of economic loss [2]. Based on this, in tunnel excavation for this project, the engineering unit must pay enough attention to its support work and select scientific and reasonable support technology to implement engineering support based on the actual situation. This is to ensure the smooth progress of tunnel excavation construction and to prevent casualties and property losses caused by tunnel collapse. Due to the limitations of the construction conditions of this project, ordinary concrete support methods are difficult to keep pace with the excavation progress. Moreover, due to the long construction period of this project, it is difficult to seal the surrounding rock immediately after the completion. Therefore, after careful consideration of many factors, the engineering unit decided to use shotcrete anchor support technology for support construction. This article analyzes the application strategy of this technology in this project [3].

3. Analysis of the application of shotcrete anchor support technology in highway bridges and tunnels

3.1. Formulation of support plan

In using shotcrete anchor support technology to support highway bridge-tunnel excavation construction, the formulation of scientific and reasonable support plans is the key to ensuring the smooth implementation of this technology and controlling the overall support effect [4]. Based on this, relevant units and staff must scientifically formulate specific support plans based on the actual project to give full play to the application advantages of shotcrete anchor support technology and ensure that the excavation construction of such tunnel projects is well supported.

According to the actual situation of this highway bridge-tunnel project, the construction unit relied on a specific engineering design. After comprehensive research and judgment in many aspects, the initial support plan was scientifically formulated. During the construction, 25 mm diameter hollow grouting anchors and R22 self-propelled anchors were used as main anchors and 22 mm diameter mortar anchors were used as tunnel arch system anchors. C25 concrete is the main concrete type in anchor support and is equipped with sufficient steel frame shotcrete anchor nets and ordinary shotcrete anchor nets. The steel frame shotcrete anchor net signals are I12.6, I20b, and I16, and they are also equipped with an adequate grille steel frame. The construction of grouting anchors is mainly carried out by anchor trolleys, and prepared concrete mortar is injected into the anchor holes. When steel pads are used as supporting structures during integral anchor construction, they must be set strictly according to the designed position during construction. According to actual engineering requirements, all steel frames used in construction must be manufactured off-site, transported to the site by transport vehicles, and directly connected inside the tunnel through bolts [5]. After checking and confirming that the construction section meets the actual requirements, the construction personnel can carry out concrete spraying construction through wet spraying. The steel mesh must also be fabricated off-site and then welded into a single piece inside the tunnel entrance. After completing the installation of anchor rods, grids, and steel frames, construction personnel can carry out anchor spraying construction [6].

3.2. Mortar shotcrete anchor construction

Mortar shotcrete anchoring is a key process link in the overall shotcrete anchor support construction, and its construction quality will directly determine the subsequent shotcrete anchor support effect. Therefore, during the specific construction, the construction unit must pay adequate attention to this process link and take reasonable technical measures to carry out the construction based on the specific engineering conditions and design standards.

During this project's shotcrete anchor support construction, the final type of anchor was a mortar anchor with a threaded steel bar diameter of 22 mm. During the specific construction, the unit first reasonably determined its actual length and circumferential distance based on the engineering conditions and design requirements [7]. After that, the construction unit mainly carried out the mortar shotcrete anchor construction through the following strategies:

(1) Applying a layer of oil evenly on the anchor rod, putting it into formal construction, and screening all the mortar. It should be determined that it meets the actual engineering design standards before using it.
(2) Using the engineering design drawings to complete the drilling construction at a reasonable location. The drilling depth and distance should be set strictly per the specifications.
(3) After the drilling construction, the construction personnel should blow out all impurities in the holes with a high-pressure hair dryer.
(4) Using a grouting machine to inject evenly mixed cement slurry into the anchor hole. When grouting, the grouting pipe needs to be slowly pulled out as the grouting operation proceeds until the entire anchor hole is filled with cement slurry.
(5) After the grouting construction work is completed, the construction personnel need to insert the anchor rod into the anchor hole so that its exposed length meets the engineering design requirements and tightly integrate it with the steel mesh in strict accordance with the engineering design.
(6) Tightening the gasket through the nut after the cement mortar reaches the standard design strength [8]. In this way, the quality of mortar shotcrete anchor construction can be effectively ensured, laying a good foundation for subsequent construction.

Table 1 shows the main process parameters of mortar shotcrete anchoring in the construction of shotcrete anchoring support for this highway bridge-tunnel project.

Table 1. Main process parameters of mortar shotcrete anchoring in the shotcrete anchoring support construction of this highway bridge-tunnel project

Serial number	Project	Parameter
1	Proportions of cement, sand, and water in cement mortar	1:1:0.45
2	Proportion of cement and early strength agent in cement mortar	1:0.01
3	Cement anchoring agent model	Type 8604
4	Anchor strength control standards	52–56 MPa
5	Cement slurry curing time	5–10 minutes

3.3. Grid steel frame construction

In this project, constructing a grid steel frame is also a key link in constructing shotcrete anchor support. Based on this, the construction unit must focus on this and take reasonable technical measures to carry out construction according to the engineering design and actual conditions to ensure the construction effect of the grid steel frame and meet the actual engineering support needs.

During the specific construction, the main technical measures taken by the construction unit include the following aspects:

(1) Taking the lead in completing the production of the grid steel frame required for this construction at the prefabricated site by the engineering design standards after passing the inspection, it was transported through the transport vehicle to the construction site and bolted into place inside the hole.
(2) Setting positioning steel bars at the designed installation positions to provide sufficient convenience

for subsequent installation and construction.

(3) During the initial blasting process, construction workers need to drive wooden wedges into the grooves on the grille steel frame and reserve connecting plates according to the engineering design for subsequent installation and construction of the grille steel frame.

(4) After the initial shotcrete anchoring construction work is completed, the construction personnel need to firmly weld the positioning steel bars to the grid steel frame, fill the middle with concrete, and perform leveling simultaneously.

(5) Setting the locking anchors on both sides of the arch feet of the tunnel in this project so that the tunnel's anchors and center line are always vertical. According to the design standards of this project, during the specific construction, the construction personnel should adjust the inclination of the anchors here no more than 2°.

(6) During this process, construction personnel should strictly follow the engineering design to weld the grid steel frame and anchor rods firmly so that the overall grid steel frame has a higher strength to meet the actual support needs of this project.

(7) Arranging the connecting steel bars used to connect the grille steel frames at the longitudinal position in the grille steel frame, and welding them firmly according to the engineering design to ensure the connection effect between the grille steel frames so that it forms a whole and gives full play to its supporting role [4].

(8) After the welding construction of the grid steel frame is completed, the construction personnel should immediately carry out concrete spraying construction and cover the entire grid steel frame with concrete so that the grid steel frame and the concrete structure form a whole. This jointly resists the external load during the highway, bridge, and tunnel construction and meets its actual support needs.

3.4. Steel mesh construction

When supporting highway bridge and tunnel projects through shotcrete anchor support technology, reasonable control of the construction quality of steel mesh is a key measure to ensure the stability of concrete spray construction. Based on this, during specific construction, the construction unit must strictly follow the engineering design requirements, consider the actual conditions of the construction site, and adopt sufficient scientific and reasonable technological measures to construct the steel mesh.

In this project, the construction unit mainly takes the following measures to carry out the steel mesh construction:

(1) Straightening all the steel bar materials and removing oil stains and impurities on the materials to make them straight, clean, and tidy.

(2) According to the engineering design plan, steel bars are used to make steel mesh sheets and they are welded firmly to the inside of the tunnel to avoid shaking during concrete spraying construction and ensure the stability of the tunnel to the greatest extent.

(3) Based on the surface shape of the concrete during the initial setting, the laying construction of the steel mesh on the top of the concrete should be reasonably carried out. Under normal circumstances, the spacing of the steel bars in the steel mesh on the top of the concrete should be controlled at about 3 cm to ensure the overall support effectively. The stability of the protective structure can be fully exerted to its supporting effect.

3.5. Concrete support construction

Concrete support construction is the most critical process link in the shotcrete anchor support technology.

Based on this, in the specific road, bridge, and tunnel excavation construction, the construction unit must be strict in order to achieve a good guarantee of the quality of shotcrete support construction. Concrete support construction is carried out according to the engineering design and the actual conditions of the construction site. In this way, the anchor rods, steel bars, and concrete can form a sufficiently stable whole to support the tunnel project effectively.

The construction unit must complete the concrete support construction in two environmental modes to achieve this goal. The first is plain concrete spray construction. Its technical measures include the following aspects:

(1) Ordinary Portland cement is used as the main cement material in concrete, and hard crystalline sand and continuously graded gravel are reasonably selected according to the engineering design. It is used as fine aggregate and coarse aggregate in concrete. According to on-site test standards, various materials are evenly mixed and fully stirred to complete the preparation of concrete materials in this construction.

(2) During the initial spraying, the construction personnel need to tilt the nozzle slightly according to the actual on-site conditions, carry out concrete spraying construction on the arch behind the wall through partitioning and segmented spiral construction, and control the diameter of the spiral construction.

(3) During the spraying process, the construction personnel should make the concrete nozzle continuously move in a circular motion and control the overlapping distance of the front and rear circles.

(4) Within 1 hour after the final setting of the concrete, the construction personnel should clean the entire concrete construction surface with clean water, and then secondary construction can be carried out.

(5) After 2 hours of final setting of the concrete, the construction personnel can implement sprinkling curing treatment according to the actual situation [9]. In this way, the quality of concrete spraying construction can be effectively ensured, and strong support can be provided for the construction quality and supporting effect of the overall concrete supporting structure.

Table 2 shows the main process parameters of concrete support construction in the construction of shotcrete anchor support for this highway bridge-tunnel project.

Table 2. Main process parameters of concrete support construction in the construction of shotcrete anchor support for this highway bridge-tunnel project

Serial number	Project	Parameter
1	Fineness modulus of hard crystalline sand	> 2.5
2	Continuously graded gravel particle size	5–12 mm
3	Concrete spiral spray construction diameter	20–30 cm
4	The overlapping distance between the front and rear circles of concrete spiral spraying	1/3 diameter
5	Concrete supporting structure maintenance time	> 14 days

The second step is the concrete support construction in the water inrush area. Since it is difficult to accurately estimate the water inflow in the area where the tunnel is located when assessing the specific water inflow, the engineering unit mainly evaluates the water inflow in areas with relatively large underground runoff. The water inflow is 97025 m^3/d. Based on this, during specific construction, the construction unit needs to make reasonable adjustments to the concrete ratio used in the concrete construction based on the actual situation and carry out concrete spraying construction in order from far to near. At the same time, as the rock wall structure in the tunnel of this project is prone to water seepage problems, during specific construction, the construction unit needs to add a large amount of accelerating setting agent to the concrete to shorten its solidification time and

prevent the impact of water seepage on the rock wall. The concrete supporting structure will reduce the adverse effects, thereby ensuring the construction quality of the overall concrete supporting structure.

4. Conclusion

In summary, in the tunnel excavation construction of modern highway bridge-tunnel projects, scientific and reasonable support technology is a key measure to ensure the overall progress, quality, and safety of the construction. In tunnel construction under complex terrain conditions, shotcrete anchor support technology is more suitable than ordinary concrete support technology. Based on this, the construction unit needs to use the specific project conditions and engineering design standards as a basis, comprehensively consider multiple factors to formulate a sufficiently scientific and reasonable shotcrete anchor support plan, and adopt reasonable technical measures and process parameters to undertake construction. Only in this way can the construction quality be effectively improved and more aligned with actual tunnel engineering support needs.

Disclosure statement

The author declares no conflict of interest.

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