Journal of World Architecture, 2024, Volume 8, Issue 1
https://ojs.bbwpublisher.com/index.php/JWA
Online ISSN: 2208-3499
Print ISSN: 2208-3480

Analysis of the Application of Span-Bridge Technology for Building Highway Tunnels that Go Over Solutional Caves

Ruiquan Liu*

China Merchants Chongqing Highway Engineering Testing Center CO., LTD., Chongqing 400067, China

***Corresponding author:** Ruiquan Liu, liuruiquan@cmhk.com

Abstract: This article presents a real engineering project showcasing the application of span-bridge construction technology for building a highway that goes over a solutional cave. An overview of the project and the details of applying this technology in highway construction are provided. Besides, strategies for enhancing its construction quality are also proposed. The objective of this analysis is to improve the safety and quality of similar projects.

Keywords: Highway; Span-bridge technology; Cave penetration

Online publication: February 26, 2024

1. Introduction

Building highway tunnels that go over solutional caves is challenging considering the unique environment of caves. Span bridge technology offers significant advantages in these situations. Therefore, this technology should be applied according to the situation to achieve the best effect.

2. Project overview

The project involved building a highway tunnel over a solutional cave using span-bridge technology. The maximum depth of the tunnel was 450 m, its overall length was 5,300 m, its axial length was about 29 m, its vertical axial length was about 40 m, and its height was about 15 m. The tunnel had to penetrate a solutional cave. The natural slope of the cave was about 20°, and it contained a significant amount of groundwater. Throughout the entire cave area, there was severe water seepage, resulting in a high risk of water inflow and extremely poor stability of the surrounding rock. When the tunnel was dug to about 2,100 m, it encountered an unfilled cave that ran northeast-southwest. Due to the large depth and volume of the cave, the tunnel needs to run through the middle, and the water droplets from the cracks increase the risk of flooding. In addition, there is a large cavity in the tunnel, so conventional construction techniques cannot effectively ensure the safety of its structure. To ensure the efficiency, quality, and safety of the tunnel construction when it penetrates the cave, the spanning bridge technology was used. This article analyzes the practical application of this technology in this project and its quality improvement strategies.

3. Application of span-bridge construction technology in highway tunnel construction

For such projects, during the actual construction process, the construction unit must first address the caves and then proceed with foundation construction, floor construction, and side wall top arch construction. The following outlines the practical application strategy of this construction technology in this project [1].

(1) Cave treatment

The first step of constructing the highway tunnel was cave treatment, which involved two segments.

The first segment was backfilling the arches and uneven surfaces of the cave with slag. This procedure was done to facilitate subsequent cave treatment and excavation processes. The tunnel debris was backfilled into the cave bottom to achieve a thickness of 1–2 meters and pre-pressure treatment was performed. During this process, a staff member was assigned to observe the surrounding rock to avoid accidents caused by rock collapse.

The second step was cave support treatment. After backfilling, shotcrete shoring was carried out to provide support for the cave walls. This process involved setting anchor rods and steel mesh to stabilize the rock wall followed by spraying concrete [2]. If the cave wall was relatively unstable, or there were weak layers, they were reinforced with I-beams, and grouting was performed to prevent the wall from collapsing. **Table 1** shows the main parameters involved in the cave treatment of this project:

Table 1. Main parameters involved in the cave support treatment

Serial number	Parameter	Measurement/Type
1	Shotcrete anchor support concrete strength grade	C20
2	Diameter of steel bars in steel mesh	Φ8mm
3	Anchor length	1 m
4	Hexagonal anchor rod	1 m
5	I-beam model for reinforcement	Type I16

(2) Foundation construction

The construction of the foundation is crucial for building highway tunnels that penetrate solutional caves. Therefore, the following measures were taken to ensure smooth construction.

The first is a site survey and construction stakeout. When the excavation reached the cave area, the whole construction process was halted, and a survey of the cave was carried out [3]. The survey involved drilling the sides of the cave, general observations, and outlining the location and profile of the cave. After the on-site survey work was completed, the construction unit relied on the specific survey results to carry out construction layout on the opposite side wall, including axis layout and centerline layout [4]. If the actual conditions at the construction site could not meet its layout requirements, the construction unit had to resort to laser beams for positioning treatment in the excavation section to ensure the overall effectiveness of the tunnel excavation construction.

The next step was side wall excavation. Since there is no platform set up in this construction section, the incremental excavation method was used, which involved drilling and blasting the walls and long-distance filling. The opposite side wall was blasted subsequently to create a hole with a diameter of 2 m. After drilling and blasting, I-beams were installed at both ends of the tunnel according to the designed spacing [5]. Next, a blasting channel was constructed to facilitate subsequent blasting work. After the walls were blasted, supports were installed to complete the construction of the foundation, ensuring maximum efficiency, quality, and safety.

(3) Floor construction

Floor construction is also a crucial step in constructing such tunnels. The floor construction was divided into two processes: steel formwork construction and floor pouring.

There are two main types of steel bar formwork: free-edge side formwork and bottom wooden formwork. For the free-edge side formwork construction personnel first set up scaffolding and then fixed the bolster plate to it. Steel bars were arranged strictly according to the engineering design, with all bars prefabricated outside the tunnel. After inspection and confirmation, they were transported to the construction site and put into use. During this process, workers ensured that the bottom plate was 0.7m or lower than the scaffolding to facilitate subsequent guardrail installation and construction [6]. When the steel bars overlapped, the construction personnel ensured to make reservations according to the engineering design requirements to facilitate subsequent side wall pouring. As for the bottom wooden formwork, the construction personnel only needed to place the bolster plate directly at its designated location.

As for the floor pouring process, the concrete mixing station was set up at a suitable location. The concrete was mixed and transported to the location where it was to be poured using a tanker [7]. It is important to follow the designed ratio of ingredients for the concrete mixture and pour it onto the base of the tunnel with the correct method. During pouring, the concrete was transported directly to the pouring position through a bucket truck for layered pouring, and a plug-in vibrator was used to vibrate the concrete to ensure its density met the requirements for the concrete base of such tunnels. **Table 2** shows the main parameters involved in the concrete pouring process.

Table 2. Main parameters involved in the concrete pouring process.

Serial number	Project	Parameter
1	Concrete base plate thickness	220 mm
2	Thickness of concrete base plate layer when pouring	30 mm
3	Concrete strength grade	C35
4	The depth to which the vibrator was inserted into the concrete	5–10cm
5	Vibration time of a single vibrating point	20 s

(4) Sidewall and roof arch construction

After completing the construction of the concrete base slab and maintaining it for 28 days or more so that it reaches 80% of the desired strength, the outer lining side walls and roof arch were constructed. The construction of the side walls and the top arch mainly included the following aspects: (i) The scaffolding was installed on the bottom platform and the installation and construction of the side wall and top arch formwork steel bars were completed. Subsequently, a concrete pump was used to pour concrete for the side walls and roof arches, allowing the concrete structure of the roof arch and the outer lining side wall to be cast and formed at once. This facilitates the construction of reinforced concrete boxes [8]. (ii) The segmented pouring method was adopted when pouring the outer lining of the side walls and roof arch. The concrete was poured along the direction of the overall tunnel axis. This ensured sufficient load-bearing capacity of the side wall scaffolding, thereby achieving good construction quality and safety [9].

4. Improvement strategies of span-bridge construction technology in highway tunnel penetrating solutional caves

(1) Geological survey of the construction site

To effectively ensure the construction quality, detailed on-site surveys should be conducted at the construction site. The survey should include geotechnical engineering conditions, hydrogeological conditions, climatic conditions, cave and fissure conditions, etc. In this way, we can have a scientific and comprehensive understanding of the actual conditions of the construction site, thus facilitating engineering design and construction plan formulation.

(2) Simulating on-site construction conditions

With the continuous development of science and technology, on-site construction simulation has become a measure of technology and quality control in many engineering projects. Especially for highway tunnels that run through solutional caves, the engineering unit can simulate on-site construction situations using BIM technology and software. This allows for evaluating the effectiveness of each process flow and construction technology in the specific design and management. Technicians can import relevant parameters into BIM software to create three-dimensional digital models, aiding in construction planning [10]. Subsequently, the bridge project's simulated construction will follow set procedures and process technologies in the model. This allows for the prompt identification and rectification of deficiencies in various technological processes or construction technology applications. This ensures timely and effective optimization of the overall construction process and technical solutions. Additionally, technicians can promptly detect quality and safety hazards in actual construction and formulate response strategies accordingly with the help of the simulated construction model. This provides strong support for ensuring the application effectiveness of process technology and improving overall project quality.

(3) Effectively improve the professional level of construction personnel

To maximize the benefits of advanced construction technologies and the quality of the end product, it is essential to improve the quality of the construction workers. To achieve this, the following measures can be taken: 1) They should be briefed about the technologies, links, and techniques that will be used before the construction starts. (2) The construction personnel should be given regular training, especially for novel construction technologies or equipment to improve their skills. (3) The construction personnel should be managed properly. Strict reward and punishment schemes should be implemented to ensure the best performance and avoid mishaps. By taking these measures, the quality of the end product can be maximized and construction can be performed safely.

5. Conclusion

In summary, when constructing highway tunnel projects that go over large unfilled caves, the use of span-bridge technology is recommended. Scientific and reasonable cave treatment and engineering support are crucial in constructing such tunnels. It is essential to develop a construction plan based on the project profile and standards and implement reasonable technical measures accordingly. Additionally, conducting in-depth research and applying quality improvement strategies is crucial to enhance the application effects of various construction technologies and ensure overall project quality and safety. This approach creates favorable conditions for applying engineering technologies and effectively improves overall construction quality.

Disclosure statement

The author declares no conflict of interest.

References

[1] Liu T, 2023, Analysis of Construction Technology of Highway Tunnel-Penetrating Solutional Cave Spanning Bridge. Big Science and Technology, 2023(3): 79–81.

[2] He Q, 2023, Research on Construction Technology of Highway Tunnel-Penetrating Solutional Cave Spanning Bridge. Construction Technology Development, 2020(9): 54–55.

[3] Long Y, 2019, Construction Technology of Highway Tunnel-Penetrating Solutional Cave Spanning Bridge. Building Materials Development Orientation (Part 1), 2019(7): 266.

[4] Li W, 2019, Research on Construction Technology of Highway Tunnel-Penetrating Solutional Cave Spanning Bridge. Mingcheng Painting, 2019(5): 86.

[5] Du Z, 2019, Construction Technology of Highway Tunnel-Penetrating Solutional Cave Spanning Bridge. Shanxi Youth, 2019(10): 208.

[6] Xiao G, Li Y, He Q, 2022, Construction and Treatment Technology of Vault-Through Solutional Caves in Highway Tunnel Projects. Construction Technology Development, 49(10): 105–109.

[7] Li J, 2022, Research on Treatment Technology of Pile Foundation Caves for Highway Bridges in Complex Karst Areas. Transportation Manager World, 2022(10): 130–132.

[8] Li J, Wu J, 2022, Reinforcement Construction Technology of Grouting Steel Pipe Piles on Weak Foundations of Filled Karst Caves in Mountainous Highway Tunnels. Western Transportation Science and Technology, 2022(9): 115–117.

[9] Peng Y, Chen Z, Wang B, et al., 2023, The Construction Method of Highway Tunnels Passing Through Pressure-Filled Caves in Solutional Cave Areas. Yunnan Hydropower, 39(2): 171–175.

[10] Wu H, 2022, Research on Construction Technology of Large Solutional Cave Arch Bridge Spanning Railway Karst Tunnel. Engineering and Construction, 36(6): 1762–1765.