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SUPERENGINEERING

Yu ZHONG

Technical innovation for Sanyang Road Cross-river Tunnel Project

Project Owner: Wuhan Metro Group Co., Ltd.
Design Company: China Railway Siyuan Survey And Design Group Co., Ltd.
Construction Companies: Shanghai Tunnel Engineering Co., Ltd.; China Railway 18th Bureau Group Co., Ltd.; Wuhan Municipal Construction Group Co., Ltd.; China Railway 2nd Bureau Group Co., Ltd.; China Railway 4th Bureau Group Co., Ltd.; China Railway 5th Bureau Group Co., Ltd.; Hanyang Municipal Construction Group Co., Ltd.; China Railway 11th Bureau Group Second Engineering Co., Ltd.; China Railway Wuhan Railway Electrification Bureau Group Co., Ltd.
Supervision Companies: Beijing Dongfang Huatai Construction Supervision Corporation; Shanghai Municipal Engineering Management Consulting Co., Ltd.; Guangzhou Railway Construction Supervision Company; Beijing Panshi Supervision Co., Ltd.; Chongqing Liansheng Construction Project Management Co., Ltd.
Construction Safety Consulting: Huazhong University of Science & Technology

Wuhan lies on two rivers and holds hundreds of lakes. The two rivers separate Wuhan and create a unique urban pattern and a tripartite equilibrium of three towns. Thus, the development of rail transit is the best choice for the convenience of Wuhan citizens in performing their activities. The Wuhan Metro Network has 16 cross-river passages (including the Changjiang and the Hanjiang rivers). The development of the river system and the complex topography with the integration of mountains and rivers in Wuhan poses a challenge to the construction of a metro cross-river tunnel in the city.

The first-stage project of Wuhan Metro Line 7 is approximately 31.3 km long. The rail transit, which passes through Jinying Lake New Town Group, Hankou and Wuchang Binjiang Activity Areas, and South Lake Group, is an important development axis running across the Changjiang River Economic Belt. It is an important passenger traffic corridor connecting Hankou and Wuchang and cross-river channel in the main city. Sanyang Road Yangtze River-crossing Tunnel Project refers to a cross-river project involving the combined highway and railway construction of Wuhan Metro Line 7 and urban road. Its main line is 4.66 km long and has eight ramps. The tunneling shield section of the combined highway and railway construction is 2.59 km long. The total investment of the project is approximately 7.39 billion CNY. Φ15.76 m Super-Large Slurry Balance Shield is used for the tunnel construction. The tunnel's outer and inner diameters are 15.2 and 13.9 m, respectively. The concrete shield segment is 650 mm thick and 2 m wide. The minimum semi-diameter of the tunnel is 1200 m, and the maximum longitudinal grade is 3.0%. The tunnel project is the largest of diameter shield tunnel project in China and the third largest in the world. Moreover, it is the world's first combined highway and railway construction shield tunnel.

The Sanyang Road Cross-river Tunnel Project mainly includes a cross-river large shield section, metro line tunnel section in Hankou and Wuchang, and both sides of the road with four ramps each. The cross-river large shield tunnel's inner and outer diameters are 13.9 and 15.2 m, respectively. The tunnel is arranged in three layers. The ventilation system of road tunnel is on the upper layer, and three lanes for highway are arranged in the middle layer. Meanwhile, the lower layer is divided into three parts: Metro Line 7 in the middle, evacuation passage for the highway and metro on one side, and ventilation system of metro and pipeline gallery for highway on the other side. For an ordinary road tunnel, the utilization ratio of the

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Yu ZHONG (✉)
Wuhan Metro Group Co., Ltd., Wuhan 430064, China
E-mail: 284127908@qq.com

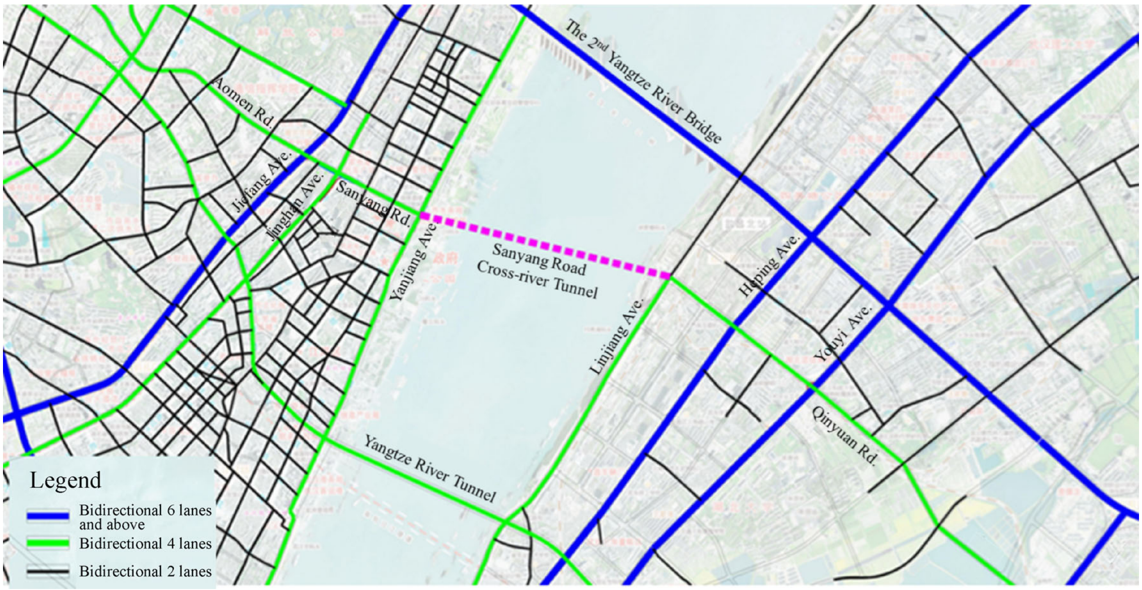

Fig. 1 Layout of Sanyang Road Cross-river Tunnel

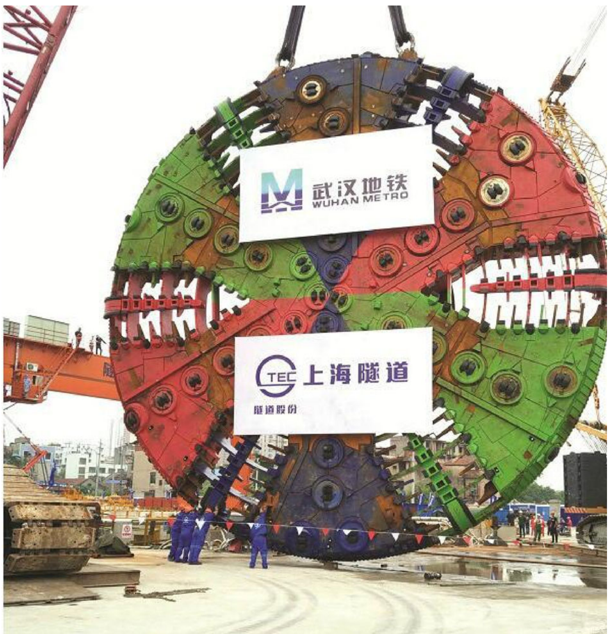

Fig. 2 Super-large-diameter cutter head of shield tunneling machine in Sanyang Road Cross-river Tunnel Project

circular section is generally in the range of 70%–85%. Thus, the inner diameter of the tunnel is controlled to be 13.9 m. The utilization ratio of the cross section is also controlled by applying a common exit passageway for the highway and railway, rail transit tunnel exit flue segment setting, local duct thinning built-in collecting sump, and similar techniques. Unlike traditional large tunnels, whose internal structures are constructed with use of prefabricated components via cast-in-site techniques, this tunnel's materials are directly transported to the shield and structural construction face through vehicles, and the internal structure of the super-large shield is constructed by using a cast-in-site plan.

The stratum where the tunnel passes through is mainly a medium dense-to-dense fine sand layer that has a local undercutting strongly weathered silty mudstone, weakly weathered silty mudstone, and weakly cemented conglomerate. The cut-in bedrock segment's total length and maximum depth are approximately 1100 and 12.6 m, respectively. The bedrock consists of soft and extremely soft rock. The uniaxial compressive strength of the weakly weathered silty mudstone and of the weakly cemented conglomerate are 0.6–5.4 and 0.1–12.2 MPa, respectively. The super-large tunnel section's monoline in the river is 2590 m long. Nearly all of the line is full-face sandy strata except for approximately 1200 m upper-soft and lower-hard composite stratum in the river. The geological conditions for shield tunneling across the Yangtze River has considerable changes.

The Sanyang Road Cross-river Tunnel is characterized by high construction cost, complex structure and surrounding environment, and short construction cycle. Many difficulties in design and construction, such as complex geological and environmental conditions, high construction difficulty, and strict technical indexes, are overcome during the tunnel construction.

The maximum excavation depth of the Wuchang working shaft, which is used as the originating well of the super-large shield, reaches 44.1 m, and the volume of the earthwork excavation is equivalent to the volume of two subway stations. This excavation is the largest-scale super-deep foundation near the river in Wuhan area. The diaphragm wall is 59 m deep. The maximum depth of the entering rock is 8 m. The total weight of the largest single-breath steel reinforcement cage is approximately 170 t. The key technology of the super-deep diaphragm wall construction is developed to ensure the safety of working shaft construction and to study a quality control method for the trench of diaphragm wall in the sandy soil and the construction technology for super-long and overweight reinforcement cage hoisting. The most advanced diaphragm wall construction equipment in the world is adopted to construct a trench of diaphragm wall with combination of grabbing and milling and to successfully solve the difficulties in super-deep foundation construction in silty sand stratum.

When the large shield is pushed forward to the middle of the river, a shield cutter head cuts in conglomerate and silty mudstone. The super-large diameter and the composite strata increase the risk and difficulty of the construction in geometric progression. Hence, the key technology of super-large diameter shield tunnel crossing the underwater composite stratum has been developed. It improves the thrust speed of the shield machine to two times the original one, and reduces the frequency of stopping machine and changing knife by 50%, which greatly ensures the normal

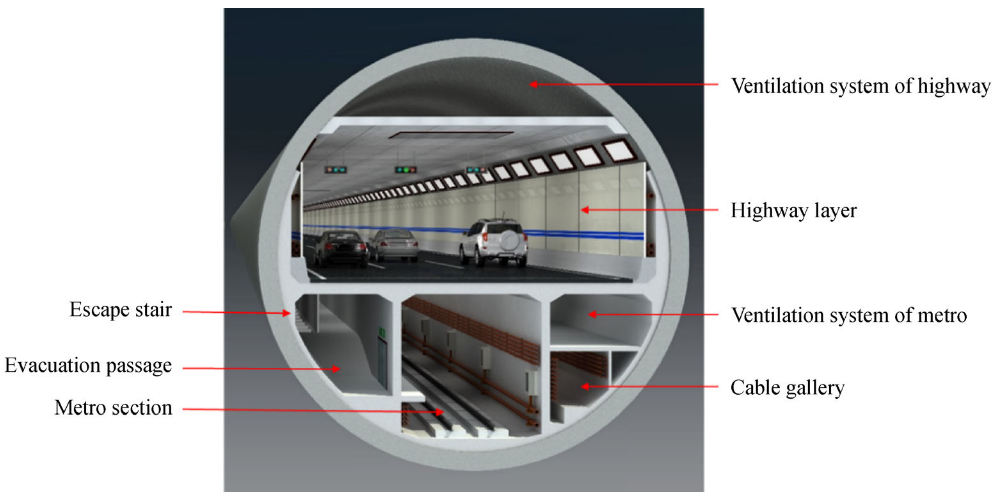

Fig. 3 Inner structure layout of horizontal section in Sanyang Road Cross-river Tunnel with combined highway and railway construction

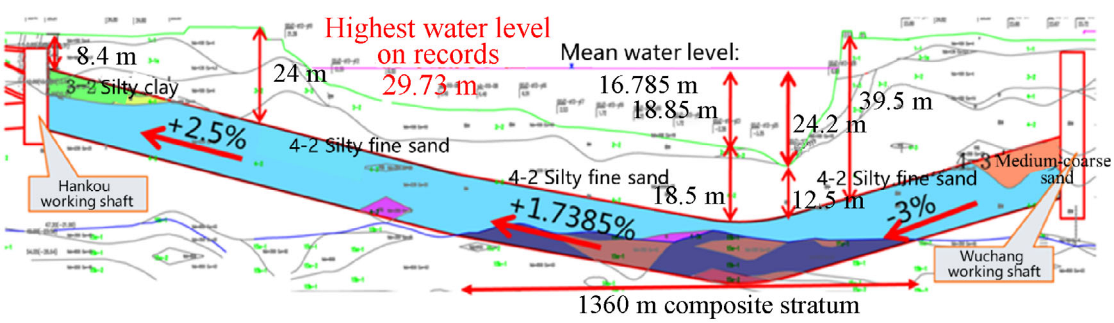

Fig. 4 Vertical geological section of Sanyang Road Cross-river Tunnel

excavation of the tunnel. The maximum water pressure in the shield segment is approximately 0.64 MPa. Therefore, the waterproof requirement is high. Especially in silty sand strata where the particle size in 0.25 – 0.075 mm accounts for 98%, leakage may lead to the loss of soil behind the duct, then lead to a chain reaction, which result in tunnel deformation and even collapse. Thus, the key technology of the design and construction of the super-large diameter non closed inner lining is mastered, and the waterproofing scheme for outside concentrating double channel and the construction scheme of lateral closed non lining structure are produced. Compared with the fully enclosed scheme, the diameter of the structure can be reduced by 0.4 m, so that the construction cost is greatly reduced. This reduction not only guarantees the safety of the tunnel structure, but also improves the economic efficiency of the project.

The working shaft in Hankou landward is used as the receiving shaft of the super-large shield tunnel. On the ground, Sanyang Road is only 40 m wide. A total of two tube tunnels are parallel in the length of 314 m from working shaft to the landward with a small clear distance of only 4.8 m, which is about 0.3 times the tunnel's diameter. The super-large diameter shield tunnel small clear distance parallel key technologies are studied to ensure the safety of established buildings in two tube tunnel and Hankou landward and to raise measures for strengthening and isolating intermediate strata. Jet-grouting reinforcement is constructed between tunnels and in the range of 0.3 m above and below the tunnel. An isolating pile is added between the tunnel and adjacent buildings to reduce the influence of super-large diameter shield tunneling on the existing tunnel and established buildings. The difficulties in the construction of shield tunnels in the downtown area, such as the minimal spacing and ultra-shallow earth shield, are successfully overcame.

Subway stations of Line 7 in both sides of the Yangtze River and the highway and railway combined construction segment are large-scale transfer stops with a complex structure. A comprehensive technology for transformation of highway and railway separated and combined construction is proposed to improve the design's quality. The separation of upper highway and lower subway tunnel is completed through construction of the conversion well in the range of 60 m working shaft. The unified planning, unified design, and unified construction of the super-large diameter highway and railway combined tunnel are accomplished to solve the problem on natural transition between urban highway and rail transit. The combined construction scheme of wind tower and super high-rise building is adopted on both sides of the cross-river tunnel to integrate the original independent wind tower into the urban landscape, which forms a green ecological construction technology. This scheme not only improves the land use efficiency of the urban center, but also reduces the impact of the project on the environment. It realizes the harmonious development between human and nature.

In this work, the entire life cycle intelligent control in tunnel structure design, production, transportation and installation, and monitoring research and application are carried out. The key technology of digital management and control for the construction of super-large-diameter tunnel based on BIM is proposed. The corresponding control system and complete set of equipment are developed to monitor the entire pass of the tunnel tube. Specifically, we develop a tunneling parameter analysis system that is based on BIM for the super-large-diameter shield. We also

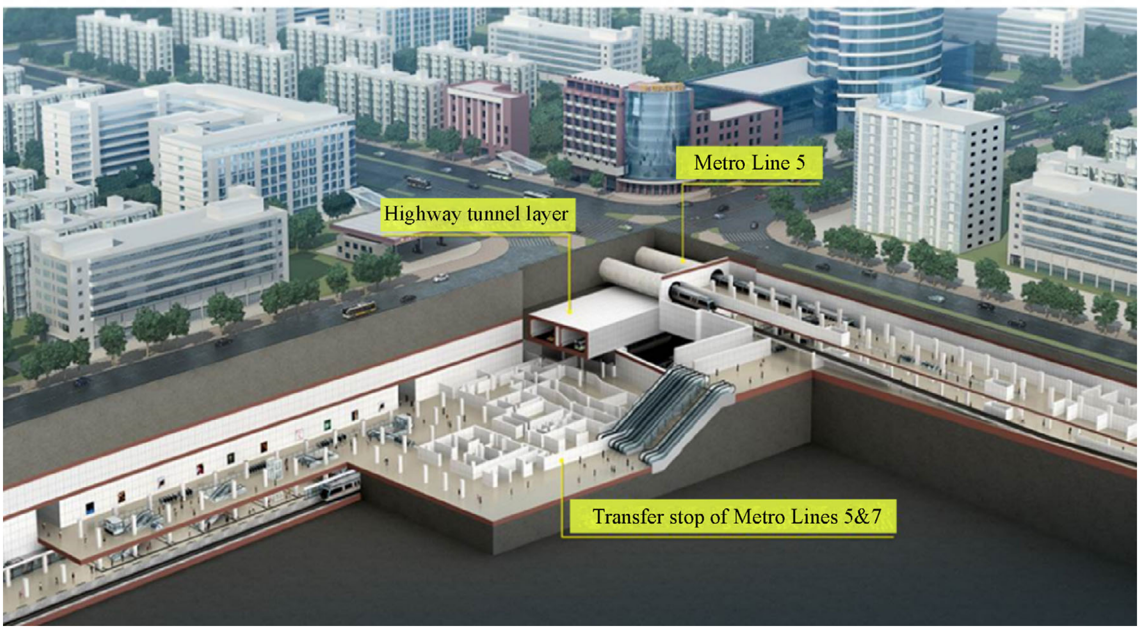

Fig. 5 Impression drawing of Xujiapeng Station in section view

master remote visualization management interface technology for shield tunneling parameters on the basis of BIM, reasonable interval control technology of shield tunneling parameters based on stratum adaptability, and many key technologies. We develop a segment assembly for the super-large-diameter shield tunnel and forming a quality forensics system-based BIM. We realize quality inspection of tunnel segment assembly molding via three-dimensional laser scanning, nondestructive examination of grouting effect behind the duct wall, and duct quality recording system. We establish a visual management and control system for super-large-diameter shield tunnel construction via BIM. We control the construction by using quality, progress, contract, and structure control modules and then generate feedback information and data. Thus, we realize the construction plan optimization on the basis of BIM, the construction quality and progress monitoring, and the error control during the construction. Through the BIM model-associated database, various data are collected, split, and analyzed to provide managers basis for business decision making. Through the research and application of the above intelligent construction key technologies, the integrity, balance, uniformity, and continuity of the construction information of the super-large-diameter highway and railway combined construction shield tunnel are ensured, and the transformation of the tunnel construction from the traditional management mode to the intelligent management model is realized.