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News & Highlights

The Hong Kong–Zhuhai–Macao Island and Tunnel Project

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The Hong Kong–Zhuhai–Macao (HZM) Bridge is located at the Pearl River estuary and has a total length of 55 km. The HZM Bridge's main navigational crossing is by way of two 100 000 m^2 artificial islands and a 6.7 km long undersea tunnel, which are the link's most critical parts. The tunnel sits on a soft layer foundation with a thickness greater than 30 m. To reserve navigational clearance for 300 000 deadweight tonnage (DWT) oil tankers in the future, the buried depth of the tunnel is up to 22 m. The project is exposed to the Lingding Channel, where typhoons, severe convection, and monsoons occur frequently. In addition, the project is in close proximity to the Chinese white dolphin core protection area, and 4000 vessels cross the project work site per day. These factors present great challenges in environmental protection and work safety. The HZM Island and Tunnel Project has been built under a design-build contract; the work scope covers the geological survey, design, research, facilities development, and construction. Along with the work, the project completed more than 240 specific subject studies and received 540 patents. After six and a half years of construction, the successful installation of the closure joint on 2 May 2017 marked the complete connection of the tunnel.

To maintain the schedule, deep-insertion and large-diameter steel cylinder techniques were developed in order to build the artificial islands rapidly. Each cylinder has a diameter of 22 m, a maximum height of 50.5 m, and a weight of nearly 500 t; they were manufactured in Shanghai, and transported to the construction site by 70 000–90 000 DWT offshore sailing vessels. A total of 120 cylinders were used to form the two artificial islands. To ensure the stability of the cylinders, it was necessary to drive them into the deep ground in one piece; to realize this technology, a corresponding design methodology was developed, a drivability analysis was performed, and the challenge of a synchronized vibration system involving eight hammers was conquered. To realize the large ratio surcharge and preloading, an integrated type of circular steel cell was innovated, which works with the steel cylinder to form a water-sealing island wall structure. Soil improvement and consolidation were then completed in only 100 days. This solution reduced the marine dredging volume by 3×10^6 m^3 and eliminated the need to construct a diaphragm wall more than 1000 m long or create a pile foundation of buildings on the artificial islands. It took only seven months to form the two artificial islands; in fact, the schedule turned out to be two years in advance of the original plan.

The immersed (tube) tunnel has 33 tunnel elements; each element was submerged on the sea bottom and then covered. The typical tunnel element is 180 m long, 38 m wide, and 11.4 m high, and has a mass of 76 000 t. The foundation work was difficult because the work had to be performed continuously in a sedimentation environment. All tunnel elements were placed on slopes with varied longitudinal gradients of 0%–3%. The water depth of the foundation work was up to 50 m at the deepest point, and the typical tunnel element's bottom area was 8000 m^2; regarding the bottom area, the contact surface of the placed gravel bed had a leveling requirement of not greater than 4 cm. To achieve these criteria, the project invested nearly 3 billion CNY to develop specialized facilities, a deep-water survey technique, a high-accuracy dredging technique, a sedimentation removal and control technique, and a deep-water foundation layer construction technique. For the prefabrication of the tunnel elements, 1 billion CNY was invested to build an immersed tunnel element prefabrication factory on a massive scale. This is only the second time that an immersed tunnel factory has been built; the first case was for the Oresund Tunnel [1]. It is the first time that curved tunnel elements have been prefabricated by a factory method; furthermore, crack control involving the casting of self-waterproofing concrete with a volume of nearly 1×10^6 m^3 was realized. The project continuously and safely installed 33 immersed tunnel elements; in addition, developments were made during the process to the following techniques: ① the large-volume element-towing technique, used for offshore and confined navigational channels; ② the deep-water and deep-trench tunnel element-installation technique; ③ the deep-water fully automatic immersion system; and ④ the adjustment-free immersed tunnel element underwater-installation technique. Moreover, the new structural concept of a semi-rigid element in an immersed tunnel was studied in order to increase the longitudinal robustness of the structure and solve the problem of high overload due to the deeply buried tunnel position. The novel concept of a composite foundation layer for an immersed tunnel was innovated in order to control the settlement and differential settlement at a relatively low magnitude. (Some data regarding past immersed tunnel projects have been published in Ref. [2].) An active water-stop integrated closure joint technique was innovated in a breakthrough to ease the difficulties of the final underwater connection. Based on trial-and-error experimentation, "memory bearing" was invented in order to mitigate the risk of

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structural damage or cracking as a result of differential settlement at the tunnel immersion joint.

In 2013, after the invasion of the super-severe Typhoon Haiyan, the project engineers evaluated the project's hazard standards in terms of the local development tendencies for hazardous weather, and optimized the project's design for hazard prevention and control, thereby comprehensively increasing the construction site's hazard-prevention capability. During construction, the project successfully withstood a frontal attack by Typhoon Hato. At present, the project has reached the last stage of finishing touches; by the end of 2017, the fundamental conditions are planned to be in place, and the tunnel will be opened to traffic.

References

[1] Busby J, Marshall C. Design and construction of the Oresund tunnel. Civil Eng 2000;138:157–66.

[2] Grantz WC. Immersed tunnel settlements: Part 2: Case histories. Tunn Undergr Sp Technol 2001;16(3):203–10.