

Design of the Gongbei tunnel using a very large cross-section pipe-roof and soil freezing method



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ABSTRACT

The Gongbei tunnel, as a critical part of the Zhuhai connection highway of the Hong Kong-Zhuhai-Macao Bridge project, is being constructed in Zhuhai, China. The tunnel, close to the Lingdingyang bay, is located in a very environmentally sensitive location with poor geological conditions and is extremely difficult to be constructed. To ensure no interruptions to customs clearance at Gongbei Port, an innovative long-distance curved pipe roof with soil freezing method is adopted to allow a super-shallow-buried large sectional double-decked six-lane tunnel to traverse under the Port. The area of excavation cross-section is up to 337 m², however the burial depth is only 5–6 m and only 0.5 m away from the pile foundations of buildings at the Port. The pipe roof around the tunnel is made up of 36 steel pipes with a length of 257 m and diameter of 1620 mm at intervals of about 356 mm, and the soil freezing method is applied for sealing. There are daunting technical challenges such as controlling the jacking precision of the long pipe roof group, guaranteeing the precise thickness of long horizontal soil freezing, controlling the ground surface deformation of the underground excavation section, etc. The paper will elaborate on the selection of the construction method for traversing under Gongbei Port, on the basic principles of the pipe-roof and soil freezing underground excavation method, on the design of a long-distance and large sectional curved pipe roof, and the design of long-distance horizontal precise soil freezing curtain.

1. Overview

1.1. Location and scale of the tunnel

The Gongbei tunnel (CCCC second highway consultants Co.Ltd, 2013), as a critical part of the Zhuhai connection highway of the Hong Kong-Zhuhai-Macao Bridge project (Fig. 1), is adjacent to Gongbei Port, Zhuhai, Guangdong. It starts from Gongbeiwai Bridge and ends in Guangdong public security border fifth detachment Maoshengwei administrative zone, passing by an artificial island, the public security border fifth detachment, a restricted area of Gongbei Port, a boundary river and Maoshengwei, involving apartments including port and border forces, and crossing city roads many times.

The tunnel is divided into three parts, i.e. an open excavated section in the sea, an underground excavated section at the Port and an open excavated section on land. The left tunnel length is 2741.063 m and the right tunnel length is 2375 m. The underground-excavated section at the Port is a critical point of the tunnel. Limited by the surrounding environment and Gongbei Port, the tunnel is constructed with a double-deck with large cross-section traversing under the restricted area of the

port using the pipe roof and soil freezing underground excavation method.

The underground-excavated section is supported by a pipe roof, which is composed of 36 steel pipes with diameter of 1620 mm. The alignment includes an about 88 m transition curve and a 167 m circular curve. The soil between the separated pipes is sealed against water intrusion by means of a sectional horizontal long-distance precise soil freezing method. The underground section is excavated sequentially, and its cross-section is about 337 m² supported by three lining structures. There is a working shaft at each side of the section for pipe roof launching and receiving.

1.2. Main technical parameter

The main technical parameter applicable to the Gongbei tunnel is shown in Table 1.

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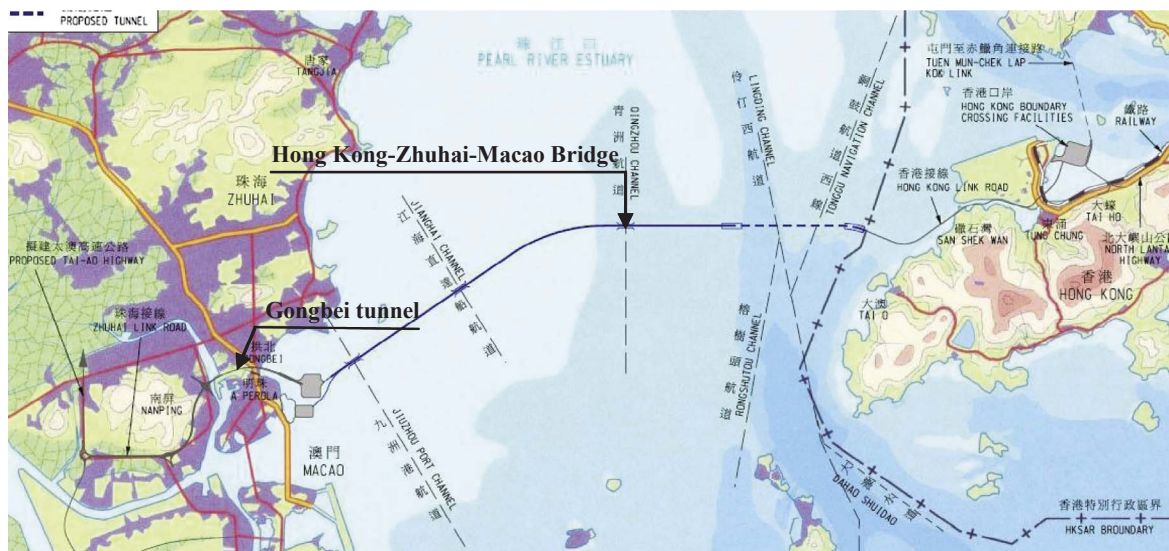


Fig. 1. Location map of the project.

Table 1
Main technical standard for tunnel.

1	Road Grade	Highway – Grade I
2	Design Speed	80 km/h
3	Number of Lanes	3
4	Width of Construction Gauge (m)	14.25
5	Clear Height of Lane (m)	5.1
6	Minimum Radius of Horizontal Curve (m)	890
7	Minimum Radius of Vertical Curve (m)	8200 m concave
8	Maximum Longitudinal Gradient	2.995%
9	Design Service Life	100 years
10	Design Load	Highway – Grade I
11	Seismic Fortification Criterion	8 degree aseismic measure, 7 degree anti-seismic calculation
12	Structural Fire Resistance Rating	Grade I
13	Structural Waterproof Rating	Grade II (Grade I for equipment room)
14	Fire Resistance Rating	3 h (RABT curve)
15	Design Flood Frequency	1/100
16	Sea Tide Controlling Level	3.47 m (construction and operation)

2. Site conditions

2.1. Engineering geological conditions

The soil stratum along the tunnel mainly includes silt, mucky soil, silt clay, muddy silt clay, coarse sand and gravel. The geotechnical characterization profile (CCCC second highway consultants Co.Ltd, 2013) of the underground-excavated section is shown in Fig. 2.

The silt and mucky soil feature high water content, high compressibility, high sensitivity, easy thixotropy and low strength, while the sand and gravel layers are highly permeable. The underground water is connected with the sea. The physical mechanical parameters of the soil strata are shown in Table 2, and samples of representative soil strata are shown in Fig. 3.

2.2. Conditions of surrounding environment

The environment around the tunnel is extremely complicated. The underground-excavated section is under Gongbei Customs. It is the biggest land port in China, and is politically sensitive. Therefore, there are high demands for environmental protection and deformation control, and it is required to ensure normal customs clearance during construction. The pipe roof at the right side of the underground-

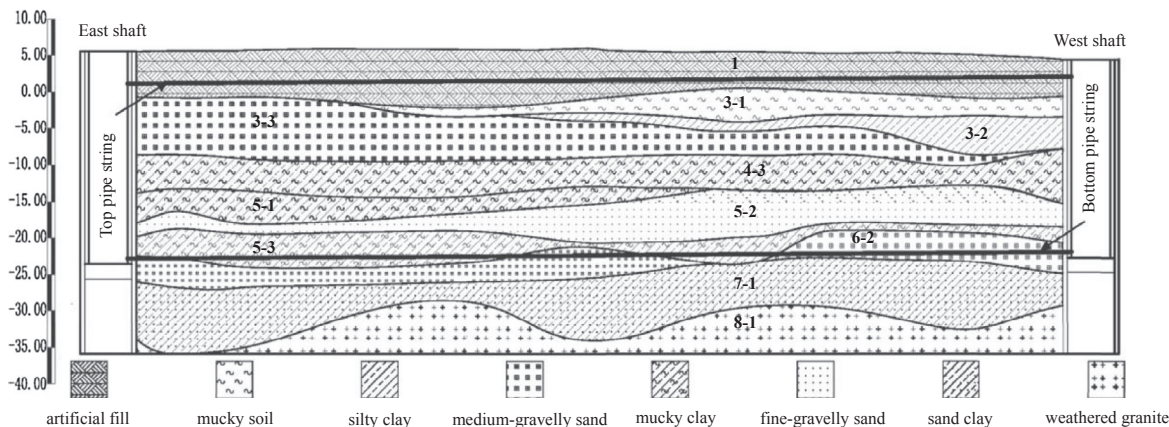


Fig. 2. The geotechnical characterization profile of the underground-excavated section.

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