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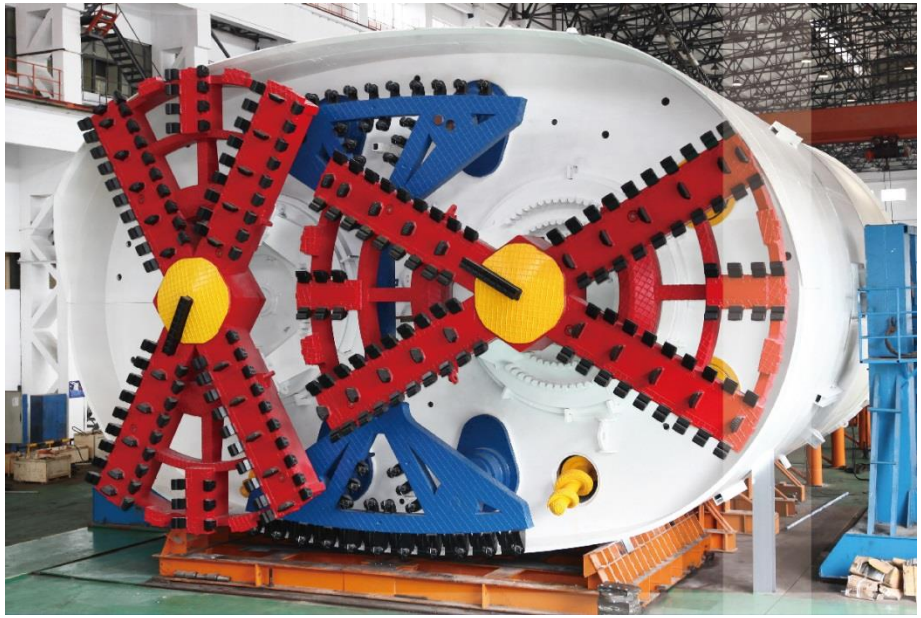
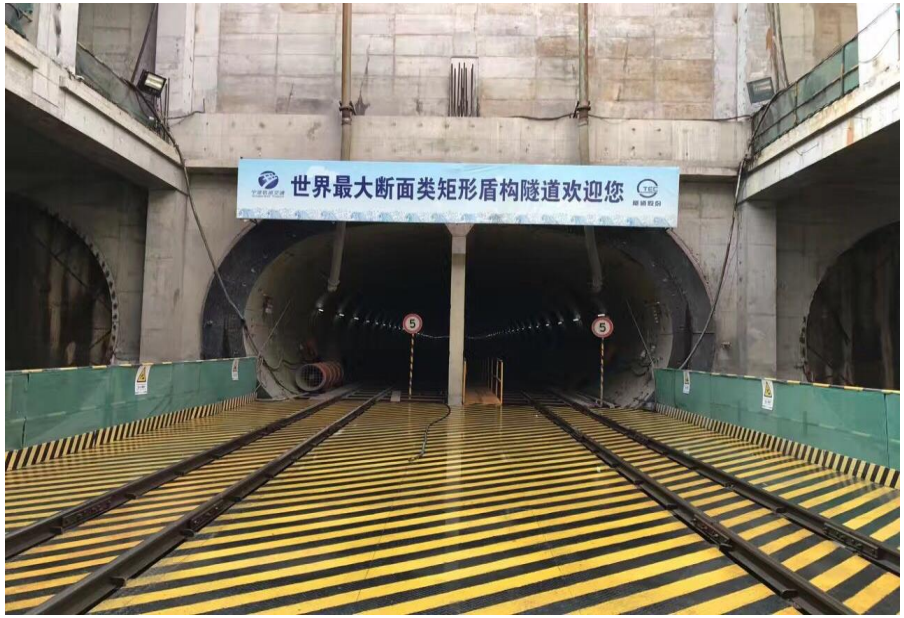
TECHNICAL PROJECT INNOVATION - OF THE YEAR -

Innovation and Application of New Single-hole Double-line Quasi-rectangular Shield Tunnel Technology System





China

Presented by :

Professor Yaohong Zhu

Ningbo University

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Stakeholders

Name	Company
Owner	Ningbo Rail Transit Group Co., Ltd.
Contractor	Shanghai Tunnel Engineering Co., Ltd.
Design	Shanghai Tunnel Engineering Rail Transit Design and Research Institute.
Fabricator	Shanghai Tunnel Engineering Co., Ltd.
Research	**Ningbo University**, Tongji University
Tech-assist	Shanghai Shield Design Test Research Center Co., Ltd.

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CONTENTS

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01 Background

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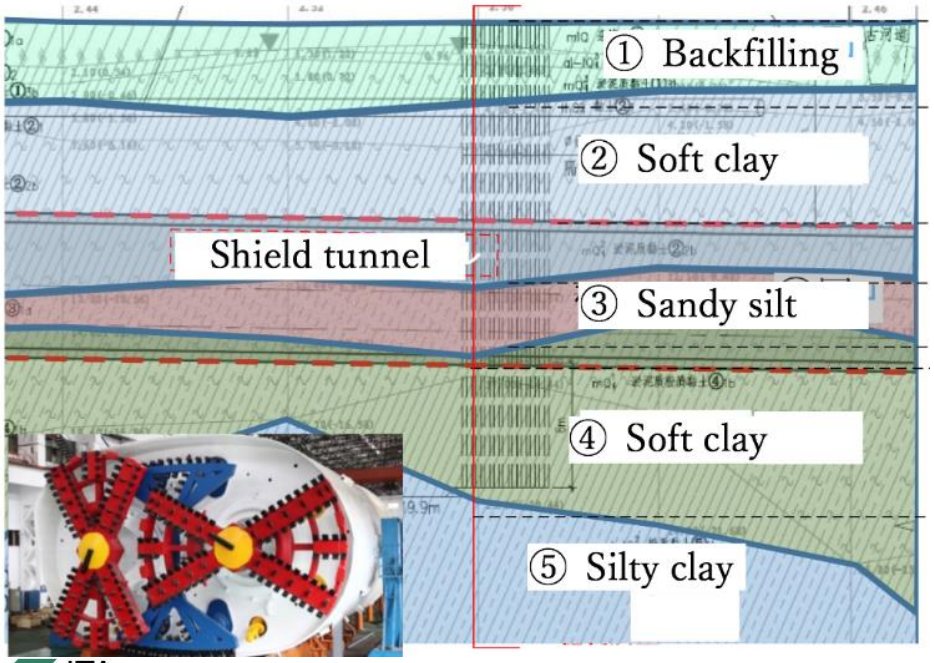
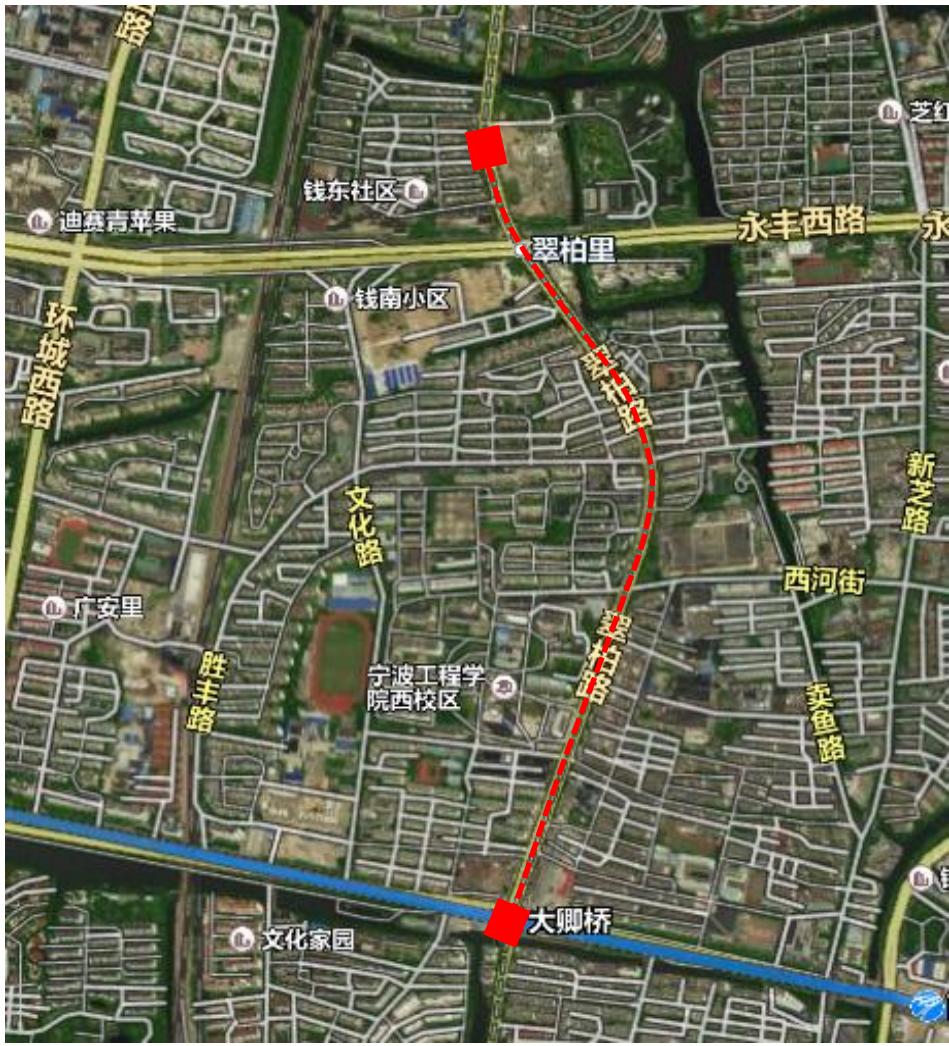
- New metro line passing the compacted center of Ningbo City, China
- Proximate aged building with pile foundation limited the construction space
- Quasi-rectangular shield tunnel is proper to these conditions





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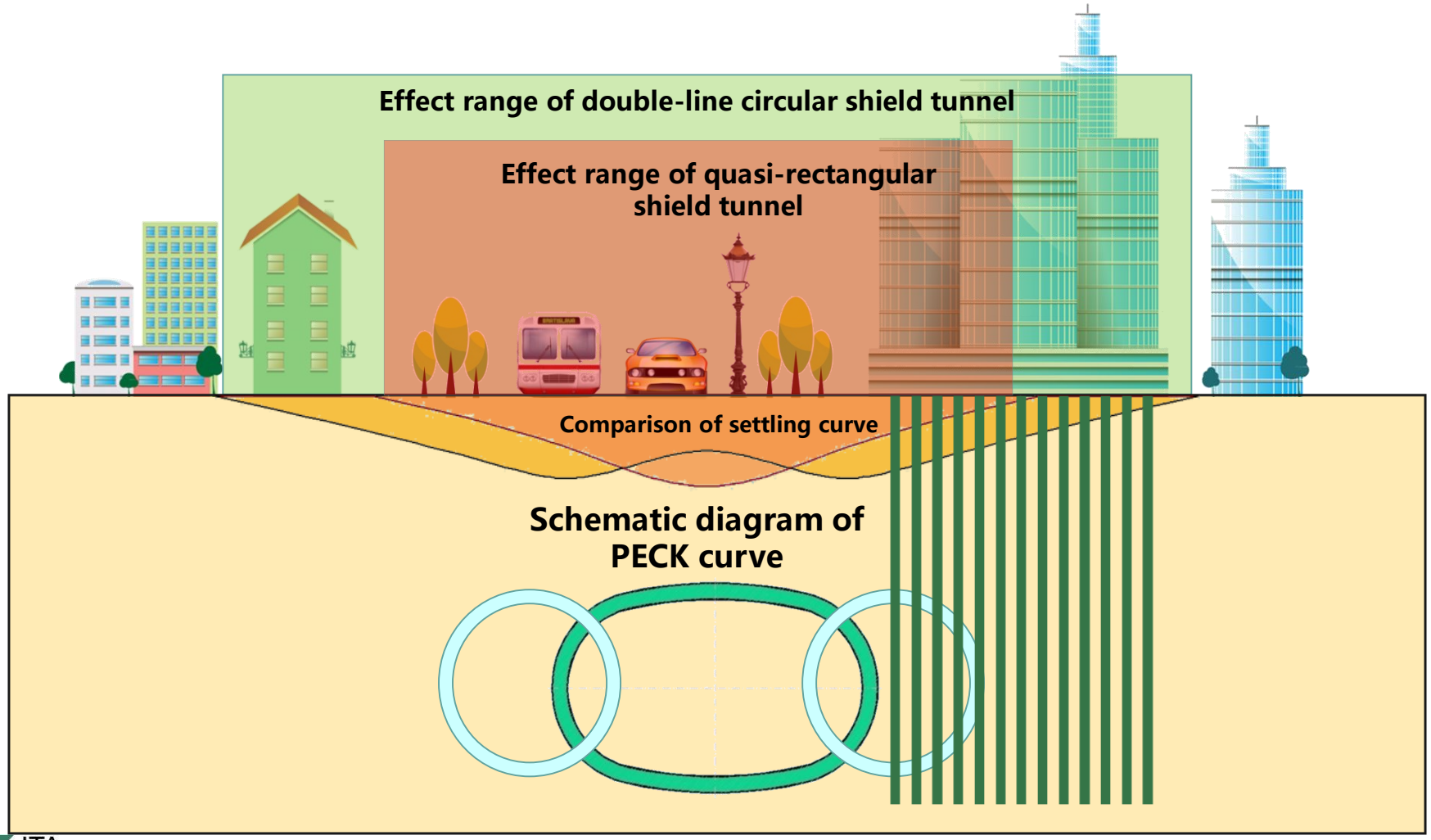

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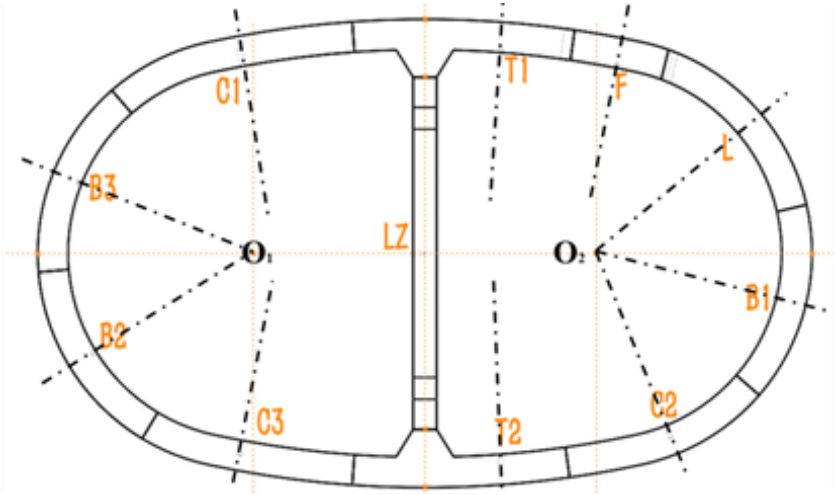

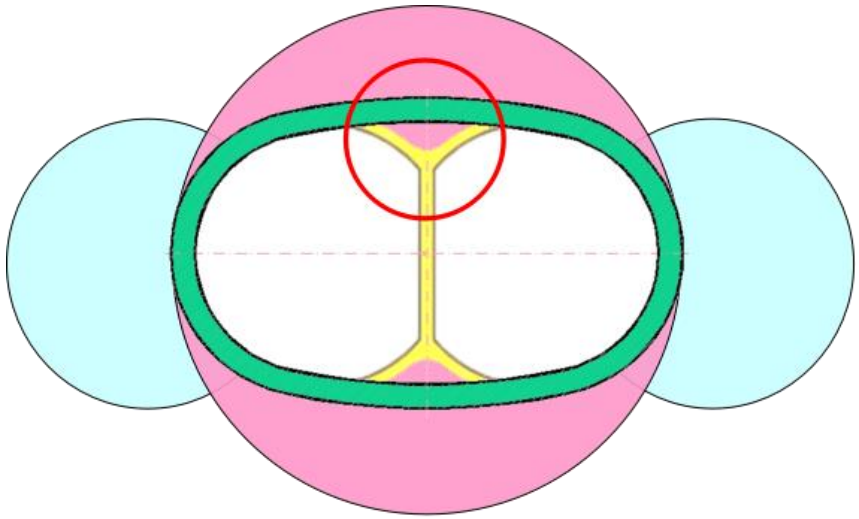

- The quasi-rectangular structure can balance space utilization, structural stress performance and settlement control capability.
- Adopting four-section arc, the force is more reasonable; thinning the thickness of the lining; facilitating full-section cutting.
- Neutral column can be set to meet fire block requirements and optimize structural stress.
- The excavation boundary of the quasi-rectangular structure is more moderate, which can avoid the back soil phenomenon and facilitate the settlement control.
- A quasi-rectangular section is slightly sacrificed compared to a positive rectangle.

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02 Quasi-rectangular tunnel introduction

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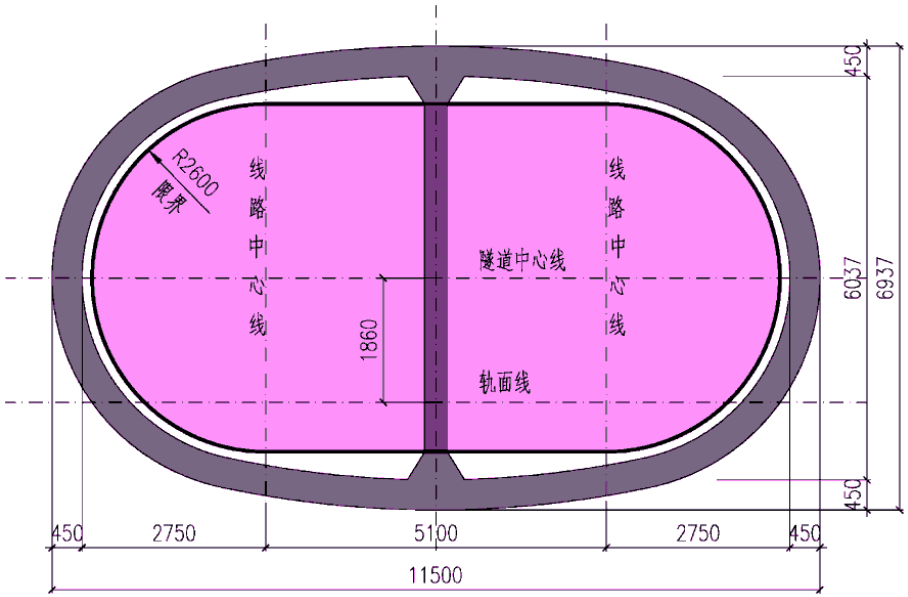

Quasi-rectangular section with column formed by four smooth tangent curves

- **High** space and section utilization;
- **Reasonable** structural design;
- **Great** strength and stiffness;

The distance between the tunnel and the surrounding buildings is increased.

The impact of shield construction on the surrounding environment is reduced effectively.

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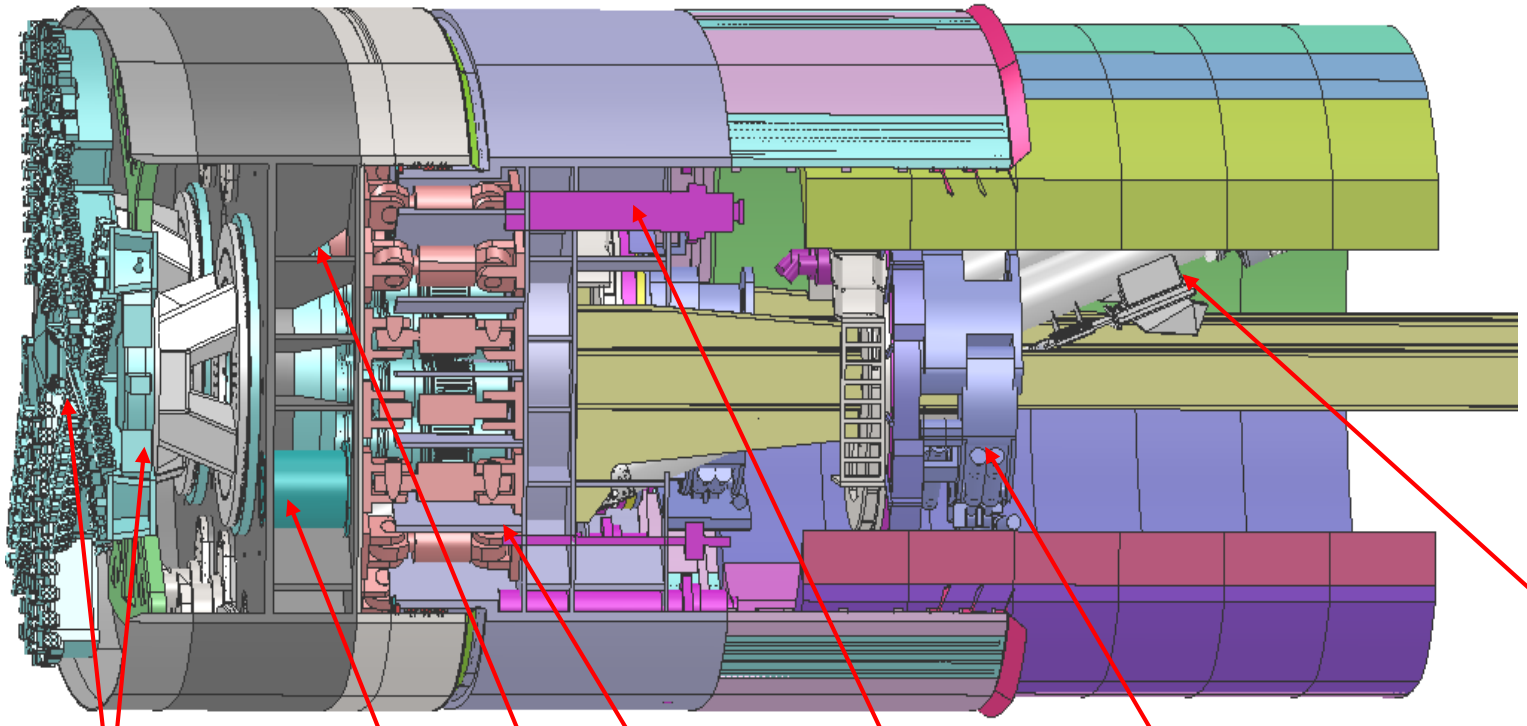

Cutter system
2 X-shaped large cutters + 1 eccentric cutter

Drive System
2 large cutter drive +1 eccentric cutter drive

Articulated system

Pedestrian gate

Propulsion system

Assembly system
2 assembly machines

Screw machine unearthing system
2 screw machines

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03 Technological innovation of Quasi-rectangular shield

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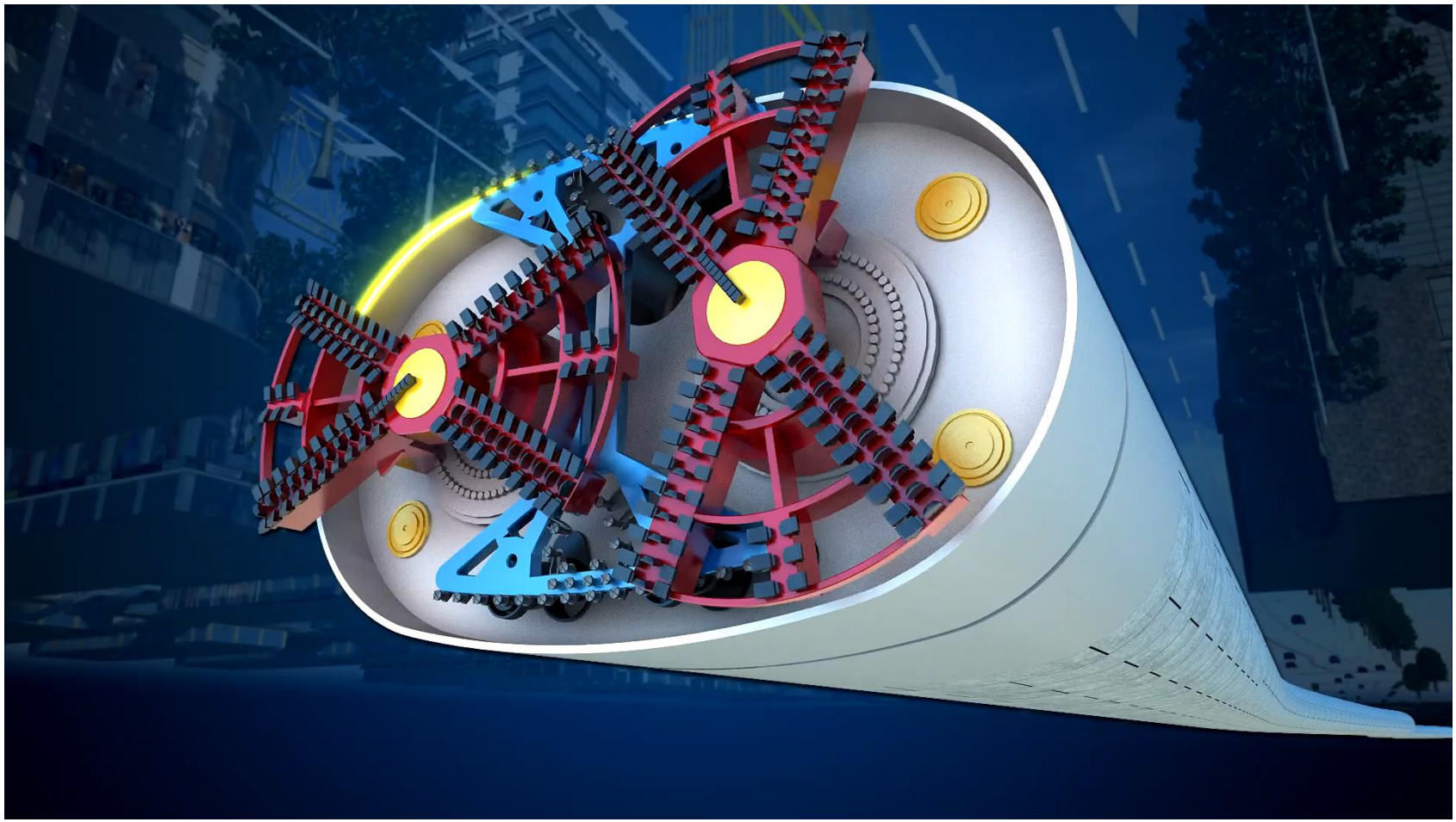

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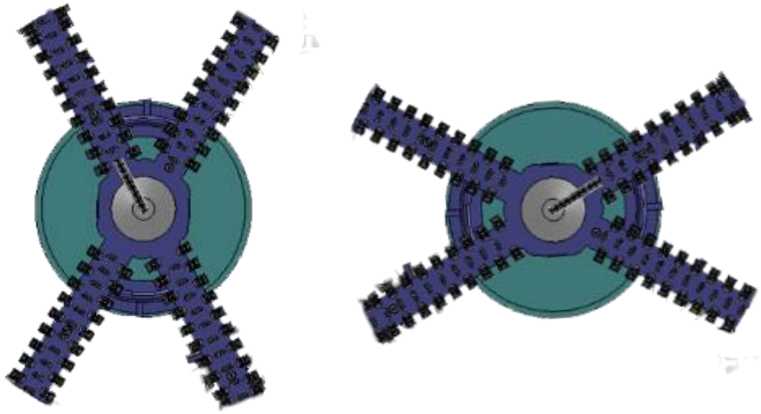
Double X-cutter drive synchronous control system with the same plane intersecting

—— Anti-interference

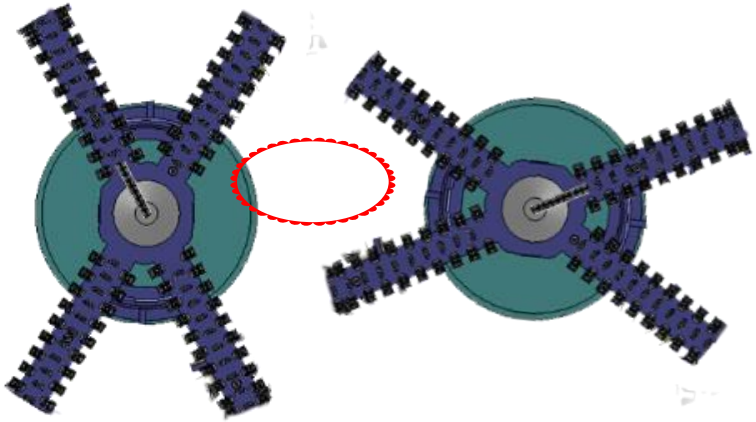
Full-section quasi-rectangular shield
Cutting on the same plane

Quasi-rectangular shield cutter monitoring system

Synchronization, anti-interference



normal status



Fault status (avoid)

- 2X+I type cutterhead Achieve 100% cutting

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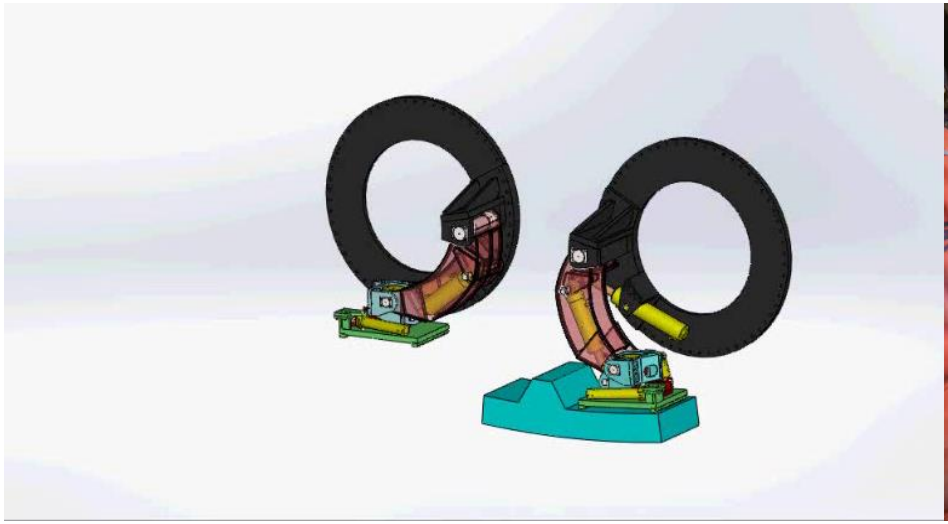

First created a assembly technology of special-shaped section series ring arm segment with 6 freedom (1 translational and 5 rotational)

Breakthrough: The traditional assembling method
Adopted： Two-machine configuration method
Achieved： Assembly of rectangular-like tunnel segments and neutral columns, assembly error can be controlled within 10mm

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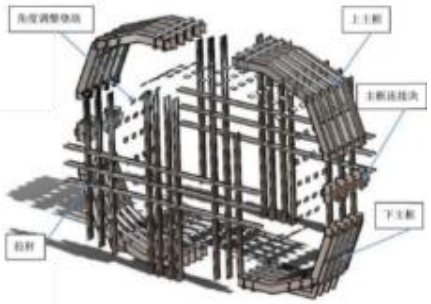

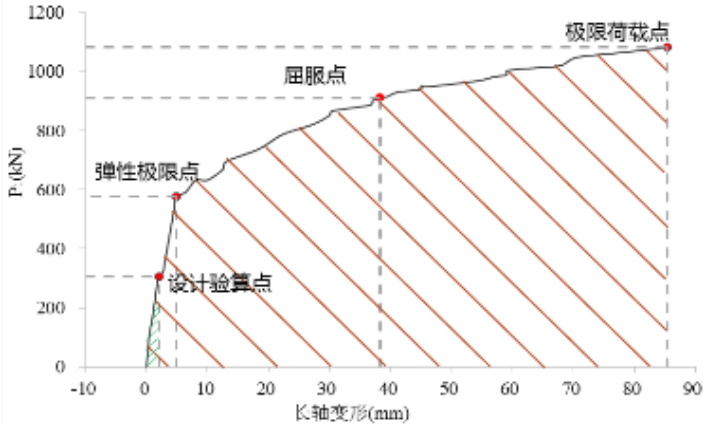

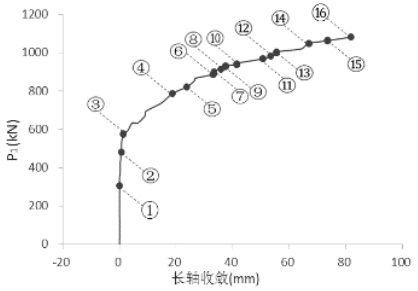

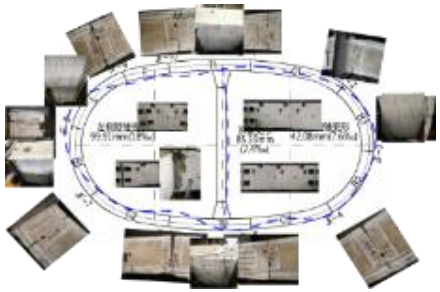

Robustness	Overload coefficient	Deformation coefficient	Ductility coefficient	Energy dissipation
Single circle	2.18	32.22	3.93	70.00
Quasi-rectangular	3.54	41.78	2.16	213.46

（1） Developed a versatile loading closed-loop pressure control test platform for standing, reclining and reconfigurable Initiatively.

（2）The bearing failure mechanism of a quasi-rectangular structure is revealed. At the same time, it is found that the quasi-rectangular structure has strong robustness compared with the existing single-circle structure, and the rationality of the structural form is verified.

（3）It is verified that the quasi-rectangular structure is extremely resistant to lateral unloading and is conducive to the sustainable development of the surrounding areas of urban rail transit lines.。

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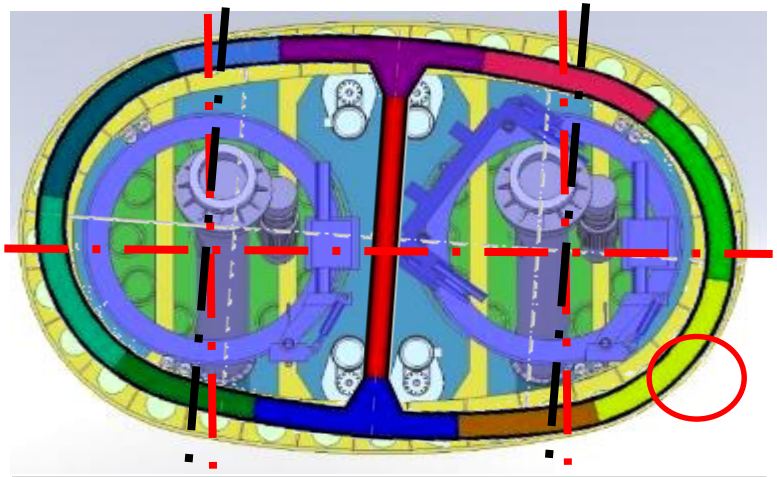

Shield rolling

Partition grouting

Unbalanced loading

Aiming at the problem of rectification and easy rolling in such a narrow-section shield, a comprehensive control method of "three-level five-class" for shield rolling prevention and control with unbalanced loading and partition grouting technology as the core is proposed.

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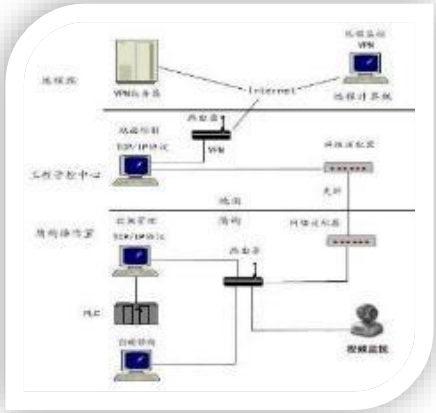
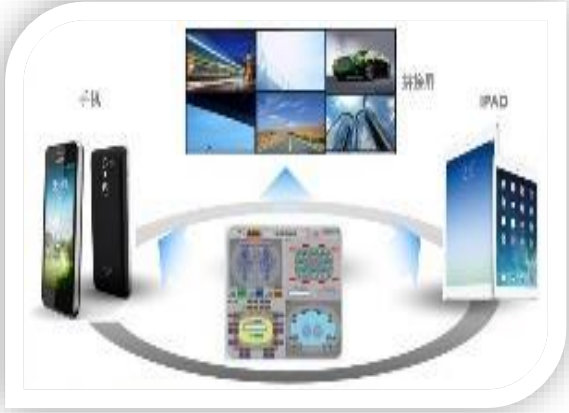


real time monitoring

Information visualization



Remoteization

A multi-data integrated control system integrating shield operating parameters, automatic guiding system, unearthing weighing system, shield tail gap measuring system, surrounding environment monitoring and tunnel deformation monitoring is established.

Realize the visualization and remoteization of construction parameters, greatly improving the efficiency of construction control.

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04 Applications

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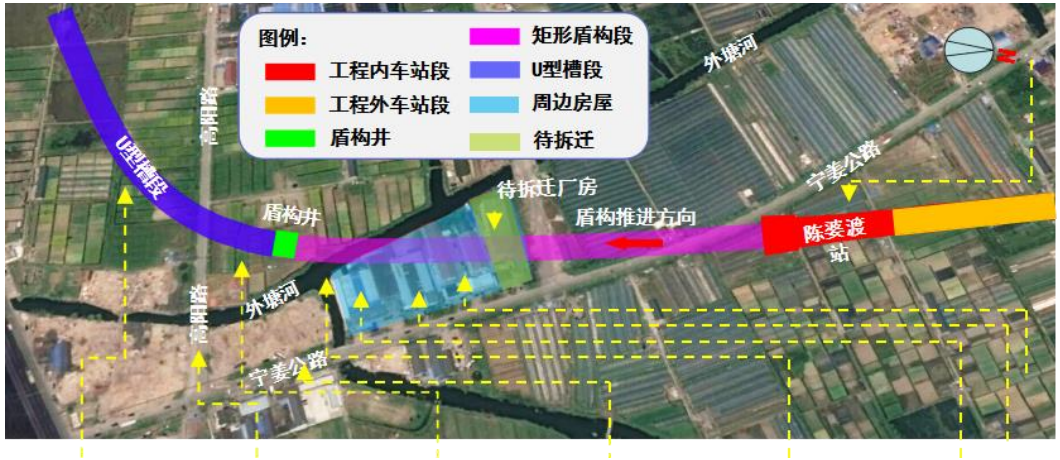

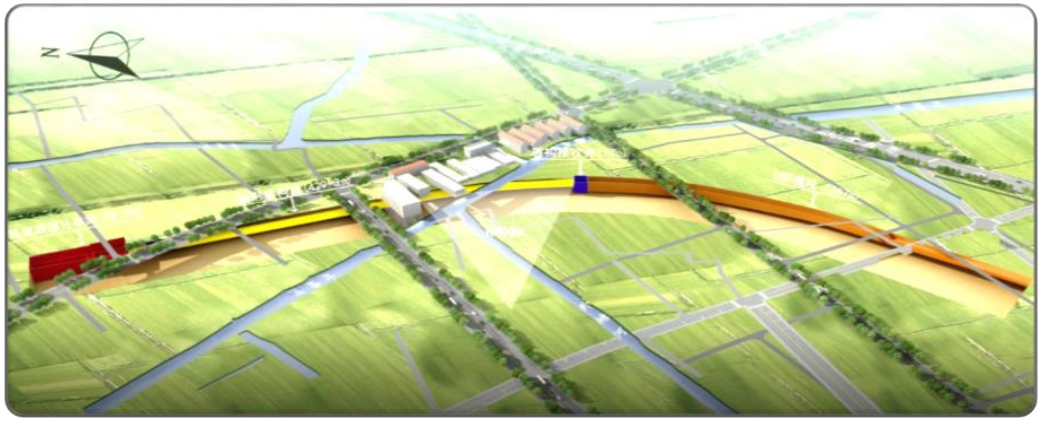

Test section project in Ningbo line 3

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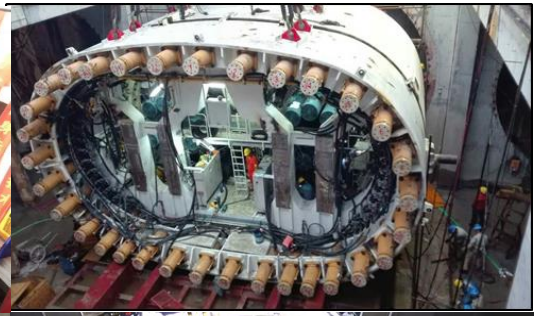

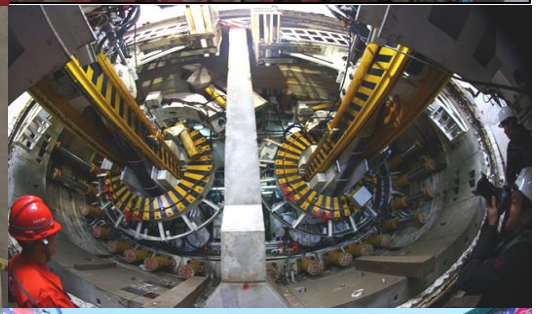

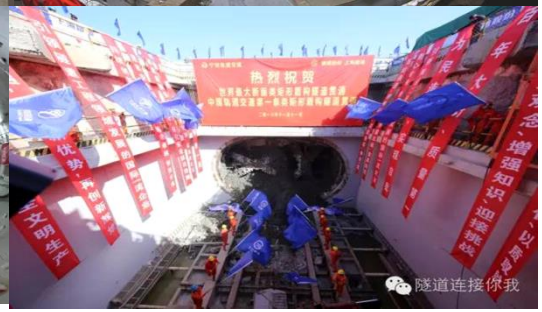

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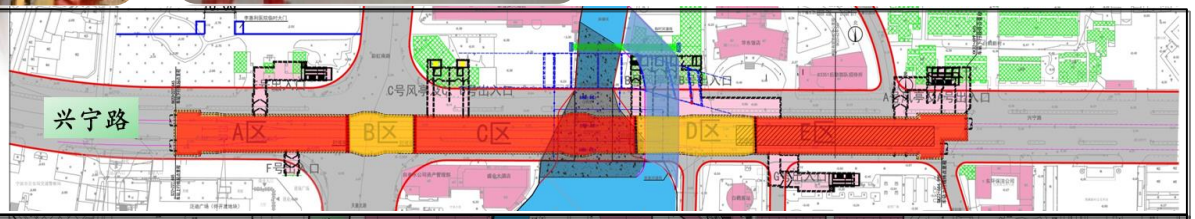
- ☐ Cui-da Section
- ☐ Feng-cong Section
- ☐ Shuang-cui Section
- ☐ Cong-zhao Section
- ☐ 3Line 3 and Line 4 enter and exit section

Ningbo District

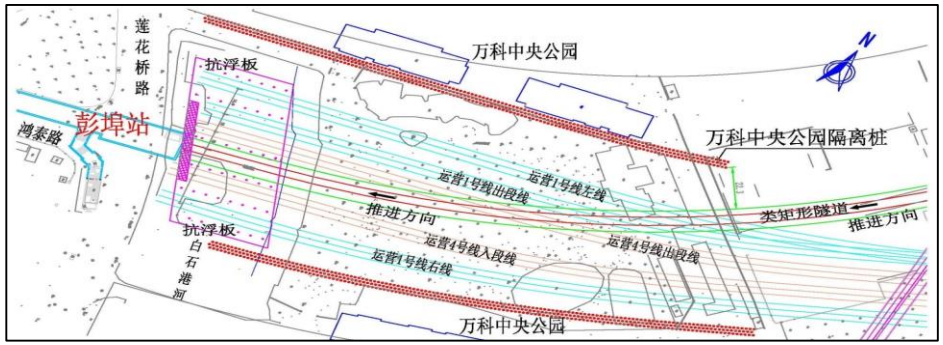
cut and cover method

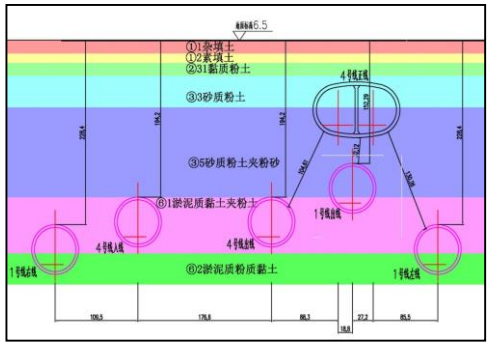


Quasi-rectangle shield and cut and cover method

Ningbo Metro Line 4

Hangzhou District





Hangzhou Metro Line 4

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05 Conclusion

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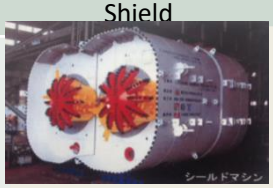
Comparison project / Technical indicators	Project technology	Similar technology abroad		Domestic similar technology	Technical analysis comparison
	Quasi-rectangular shield tunnel 	Tokyo KwonChi tunnel project open shield 	Tokyo East Line Shibuya ~ Daikanyama Tunnel Shield 	Shanghai Hongqiao Airport Underground connection Shield 	
Dimensions (cutting area)	11.83×7.27 (77㎡)	11.96×8.24 (80㎡)	10.3×7.1 (69㎡)	10.1×5.3 (51㎡)	Largest earth pressure balance boring machine in the world
Full section cutting	achieved	/	unable	unable	The only project that can achieve full section cutting
Segment form	Concrete 9+1+1 (colomn)	Complex 14+1+2 (colomn)	Complex 12+1+2 (colomn)	Complex 6 (no colomn)	The best economic type
Segment assembly machine form	1 translational + 5 rotational	2 translational +4 rotational	2 translational +4 rotational	2 translational +4 rotational (no colomn)	The best technical applicability
Minimum articulated turning radius	horizontal 1.1° Vertical 1.5° R350	no	horizontal0.5° Vertical1.5° R500	no	Better than the technology abroad; Minimum turning radius is smaller than foreign; adapt to emergency curve construction
Mud membrane anti-back soil device	Yes	no	no	no	No similar technology at home and abroad; this project can achieve optimal control of settlement

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Project Performance

- **2** Quasi-rectangular TBM
- Applied in **6 projects** of Ningbo Rail transit Line 2,3,4
- More than **5km** of tunnel excavated;
- Output value of more than **RMB 670 million**
- **Less settlement** than conventional TBM
- **Less Demolition** of nearby structure
- **2 more tunnels** to build and **over 800m to excavate**

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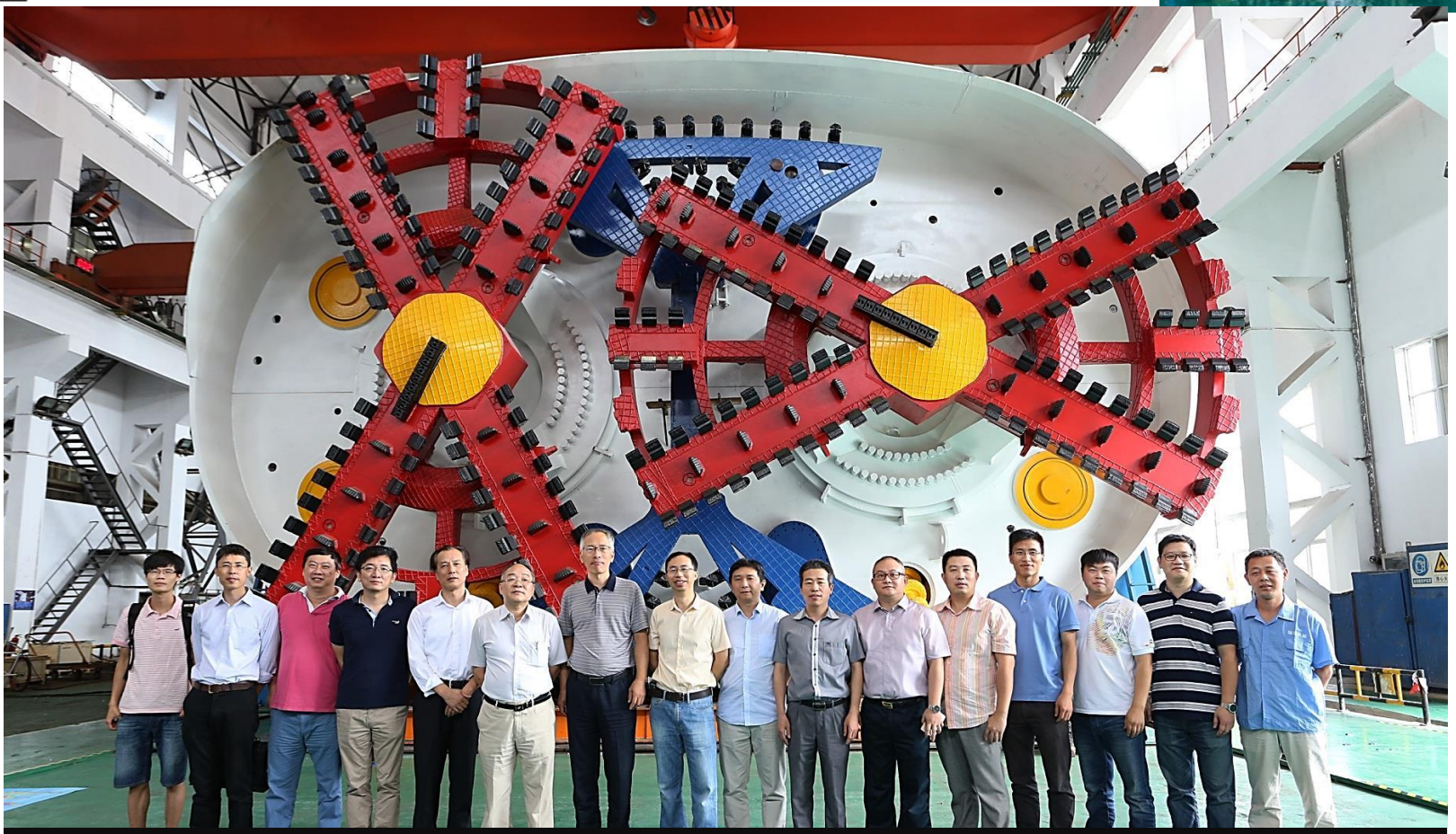

Thank you for your attention!

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