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

China

Presented by:

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Ningbo University
## Stakeholders

<table>
<thead>
<tr>
<th>Name</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owner</td>
<td>Ningbo Rail Transit Group Co., Ltd.</td>
</tr>
<tr>
<td>Contractor</td>
<td>Shanghai Tunnel Engineering Co., Ltd.</td>
</tr>
<tr>
<td>Design</td>
<td>Shanghai Tunnel Engineering Rail Transit Design and Research Institute.</td>
</tr>
<tr>
<td>Fabricator</td>
<td>Shanghai Tunnel Engineering Co., Ltd.</td>
</tr>
<tr>
<td>Research</td>
<td><strong>Ningbo University</strong>, Tongji University</td>
</tr>
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<td>Tech-assist</td>
<td>Shanghai Shield Design Test Research Center Co., Ltd.</td>
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02 Quasi-rectangular tunnel introduction

03 Technological innovation of Quasi-rectangular shield

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01 Background
• 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
Schematic diagram of PECK curve

Effect range of double-line circular shield tunnel

Effect range of quasi-rectangular shield tunnel

Comparison of settling curve
• 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.
02 Quasi-rectangular tunnel introduction
- **High** space and section utilization;
- **Reasonable** structural design;
- **Great** strength and stiffness;

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

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

The **impact** of shield construction on the surrounding environment is **reduced effectively**.
Cutter system
2 X-shaped large cutters + 1 eccentric cutter

Drive System
2 large cutter drive + 1 eccentric cutter drive

Articulated system

Propulsion system

Assembly system
2 assembly machines

Pedestrian gate

Screw machine unearthing system
2 screw machines
03 Technological innovation of Quasi-rectangular shield
Double X-cutter drive synchronous control system with the same plane intersecting

— Anti-interference

- 2X+I type cutterhead Achieve 100% cutting
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
（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.
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.
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.
04 Applications
Test section project in Ningbo line 3
Cui-da Section
Shuang-cui Section
Feng-cong Section
Cong-zhao Section
3 Line 3 and Line 4 enter and exit section
05 Conclusion
<table>
<thead>
<tr>
<th>Comparison project</th>
<th>Project technology</th>
<th>Similar technology abroad</th>
<th>Domestic similar technology</th>
<th>Technical analysis comparison</th>
</tr>
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<tbody>
<tr>
<td>Quasi-rectangular shield tunnel</td>
<td>Tokyo KwonChi tunnel project open shield</td>
<td>Tokyo East Line Shibuya ~ Daikanyama Tunnel Shield</td>
<td>Shanghai Hongqiao Airport Underground connection Shield</td>
<td></td>
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<tr>
<td>Technical indicators</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dimensions (cutting area)</td>
<td>11.83×7.27 (77㎡)</td>
<td>11.96×8.24 (80㎡)</td>
<td>10.3×7.1 (69㎡)</td>
<td>10.1×5.3 (51㎡)</td>
</tr>
<tr>
<td></td>
<td>Largest earth pressure balance boring machine in the world</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Full section cutting</td>
<td>achieved</td>
<td>/</td>
<td>unable</td>
<td>unable</td>
</tr>
<tr>
<td></td>
<td>The only project that can achieve full section cutting</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Segment form</td>
<td>Concrete 9+1+1 (colomn)</td>
<td>Complex 14+1+2 (colomn)</td>
<td>Complex 12+1+2 (colomn)</td>
<td>Complex 6 (no colomn)</td>
</tr>
<tr>
<td></td>
<td>The best economic type</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Segment assembly machine form</td>
<td>1 translational + 5 rotational</td>
<td>2 translational +4 rotational</td>
<td>2 translational +4 rotational</td>
<td>2 translational +4 rotational (no colomn)</td>
</tr>
<tr>
<td></td>
<td>The best technical applicability</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Minimum articulated turning radius</td>
<td>horizontal 1.1° Vertical 1.5° R350</td>
<td>no</td>
<td>horizontal0.5° Vertical1.5° R500</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>Better than the technology abroad; Minimum turning radius is smaller than foreign; adapt to emergency curve construction</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mud membrane anti-back soil device</td>
<td>Yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td></td>
<td>No similar technology at home and abroad; this project can achieve optimal control of settlement</td>
<td></td>
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</table>
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**
Thank you for your attention!

Miami, USA 18th November 2019

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