Mechanized Tunnelling with Large Section Horseshoe Shape EPB-TBM First Applied in Loess Mountain Tunnel at Mengxi Huazhong Railway Line Baicheng Tunnel

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Large Section Horseshoe Shape EPB-TBM in Loess Mountain Tunnel
## Stakeholders

<table>
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<tr>
<th>Name</th>
<th>Company</th>
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</thead>
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<tr>
<td>Owner</td>
<td>Mengxi -Huazhong railway co., Ltd.</td>
</tr>
<tr>
<td>Contractor</td>
<td>China Tiesiju Civil Engineering Group</td>
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<tr>
<td>Design</td>
<td>China Railway Design Corporation</td>
</tr>
<tr>
<td>Supervisor</td>
<td>Siyuan Hubei Engineering Supervision &amp; Consultant Co., Ltd</td>
</tr>
<tr>
<td>TBM Fabricator</td>
<td>China Railway Engineering Equipment Group Co., Ltd</td>
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<td>Research</td>
<td>Southwest Jiaotong University/Chengdu Tunnelkey Co., Ltd</td>
</tr>
<tr>
<td>Tech-assist</td>
<td>China Railway Engineering Services Co., Ltd</td>
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01 Introduction
Coal mine distribution in China and “the North coal to the south”

- The coal is mainly distributed in the north China. The need of coal is in the east China and south China.
- The current coal transportation route is consisted of “the west coal to the east” coal railway lines, river transportation and sea transportation.
- One north to south coal transportation railway is needed.
Mengxi Huazhong Coal Transportation Railway Line

- Total length: 1814 kilometers
- Total investment: 24.2 billion euro
- Designed transportation capacity: 0.2 billion ton/annual
Bai-Cheng Tunnel

- Located in Loess plateau, a.k.a. the Huangtu plateau
- Length: 3345m
- Dimensions: 11.9m × 10.95m horseshoe shape
- Overburden: 7m~81m
Basic information of the Bai-cheng tunnel

<table>
<thead>
<tr>
<th>No</th>
<th>Soil Type</th>
<th>Overburden (m)</th>
<th>γ (kN/m3)</th>
<th>Φ (°)</th>
<th>Cohesion (kPa)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Fine sand</td>
<td>3.8</td>
<td>19.4</td>
<td>34</td>
<td>3</td>
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<tr>
<td>2</td>
<td>New loess I</td>
<td>11.4</td>
<td>16.0</td>
<td>27.1</td>
<td>22.0</td>
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<tr>
<td>3</td>
<td>New loess II</td>
<td>29.8</td>
<td>18.0</td>
<td>27.5</td>
<td>20.7</td>
</tr>
</tbody>
</table>
Original scheme for the Bai-Cheng Tunnel

Issue to Concern Using Conventional Sequential Excavation Method (SEM)

1. Soft ground: Fine sand and Loess, especially at the portal region
2. Underpass nearby infrastructures, i.e., motorways, roads, and pipelines for gas and water supply

Result in

1. Instability of surrounding soil at the portal region
2. Instability of tunnel face
3. Heavy support
4. Hard to control ground settlement under across the nearby infrastructures
5. Extra support and protection under across the nearby infrastructures
6. Noise and dust
7. Long construction period
02 The Large Section Horseshoe EPB-TBM
Pilot project: World’s First-Ever Large Section Horseshoe Shape EPB-TBM
Key Components of the Horseshoe EPB-TBM

Main body

Face support

Jacking system

Lining installation system
Lining and Lining Installation System

Longitudinal: 44 RD30 Bolts
Transverse: 16 RD30 Bolts
Launch the TBM in the Cut and Cover Section

Cover arch

Reaction structure
Excavation

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Lining

2. Design and manufacture an installation machine for the multi-segment segment.
Belt conveyor for muck transport

Double muck system
Segment accomplish
World’s First-Ever Horseshoe Shape EPB-TBM is arrived!

Receiving

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in Loess Mountain Tunnel
03 Project Challenges
Project Challenges

- Manufacture Challenges
- Construction Challenges
- Cost Challenges
  - Surface utility Challenges
  - Obstruction encountered during tunnelling
Manufacture Challenges

1. A single circular cutterhead
   - Main bearing with large power
   - Special design and manufacture period
   - Expensive

2. Multiple horseshoe cutterhead
   - Smaller main bearing
   - Reduce 7.1 m² excavation area
   - Spatial distribution of cutterheads with little blind region
   - Lower cost
Manufacture Challenges

Uneven shape

Rolling

Countermeasures for anti-rolling

Extra weight

Anti-rolling

Clockwise and counterclockwise rotation
Manufacture Challenges

Lining Installation

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Construction Challenges

1. Instability of the surrounding soil
   A. At the portal region, the surrounding soil is fine sand, which causes the instability of the tunnel face.
   B. Due to the weight of lining and earth pressure, the segment would turn to oval shape.

Countermeasures:
   A. Synchronous grouting combining polyester polyol and isocyanate
   B. Fast hardening system of grouting
   C. Muck improving to increase fluidity of the excavation soil

Fast Grouting System
Construction Challenges

2. Obstruction encountered during tunneling

After 1064\textsuperscript{th} Ring, hard and cohesive old loess encountered. It prevented excavation.

**Countermeasures:**
Conic soil breaker added at the front of the TBM
Cost Challenges

Cost comparison
A. Cost for SEM: 54.998 million euro
B. Cost for the horseshoe EPB-TBM: 60.198 million euro

Countermeasure:
In the near future, 560 kilometers mountain tunnel in loess region will be constructed. Reuse of the large section horseshoe EPB-TBM will be possible which would decrease the manufacture cost of the machine.
04 Benefits of the Horseshoe EPB-TBM
Benefits of the Horseshoe Shape EPB-TBM

- Simpler and safer construction method
- Faster construction speed than conventional SEM
- Smaller excavation: Horseshoe shape: 104.1 m² Circular shape: 111.2 m²
- Less construction material used

<table>
<thead>
<tr>
<th>NO.</th>
<th>Comparison Factors</th>
<th>Unit</th>
<th>SEM</th>
<th>Horseshoe shape EPB-TBM</th>
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<tbody>
<tr>
<td>1</td>
<td>Excavation area</td>
<td>m³</td>
<td>121.91</td>
<td>104.10</td>
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<td>2</td>
<td>Grouting volume</td>
<td>m³</td>
<td>1.18</td>
<td>10.60</td>
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<td>3</td>
<td>Grouting pile</td>
<td>m</td>
<td>71.74</td>
<td>19.1</td>
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<td>4</td>
<td>Concrete soil mixing pile</td>
<td>m</td>
<td>28.75</td>
<td>2.45</td>
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<td>5</td>
<td>pipe</td>
<td>m</td>
<td>65.46</td>
<td>0.00</td>
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<td>6</td>
<td>bolts</td>
<td>m</td>
<td>56.73</td>
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<tr>
<td>7</td>
<td>Concrete</td>
<td>m³</td>
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<td>16.80</td>
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<td>8</td>
<td>Reinforcement</td>
<td>t</td>
<td>3.96</td>
<td>2.80</td>
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<td>9</td>
<td>Total</td>
<td>euro/meter</td>
<td>16442</td>
<td>17713</td>
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</table>
Benefits of the Horseshoe Shape EPB-TBM

- Little influence to the surface building and infrastructures
- In winter, heat preservation ensure consistent construction
- Minimum dust and human-friendly working environment
05 Conclusions
Conclusions

• Horseshoe EPB-TBM proves to a feasible solution for mountain tunnels in soft ground (approximately 560 km mountain tunnels in loess region)
• Innovative alternative to the conventional SEM at a wide range of overburdens
• A further innovation from circular section to horseshoe section for EPB-TBM
• Faster construction speed than the conventional SEM
• Less excavation volume and construction material used
• Capable of winter construction to ensure construction consistency
• Human-friendly construction environment
Thank you for your attention