Application and Prospects of TBM In The Mining Industry

中国铁建重工集团股份有限公司
CHINA RAILWAY CONSTRUCTION HEAVY INDUSTRY CORPORATION LIMITED

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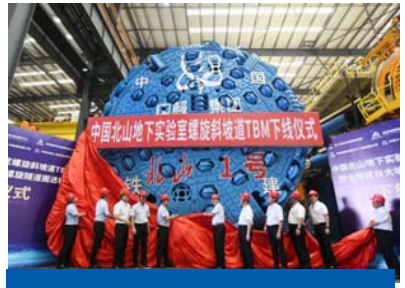
(1) Development History of Mining TBMs

Since 2010, with the support of **National Key R&D Program**, CRCHI has widely applied TBMs (Tunnel Boring Machines) in long, large, and deep tunnels for water diversion, railway, and highway projects with **substantial investment.** In 2013, CRCHI successfully developed **the world's first mining TBM**, officially launching efficient tunneling in the mining industry.

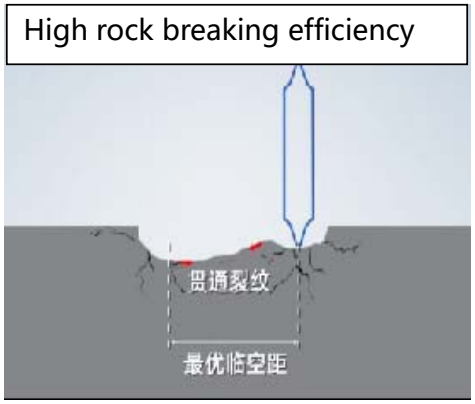
The Group's First Composite Balance TBM	**The World's First** Coal Mine Inclined Shaft TBM	**The China's First** Open TBM	**The China's First** The Largest Diameter Mining Open-type TBM	**The World's First** Large Gradient Spiral TBM
				
2010	**2013**	**2014**	**2017**	**2022**

(1) Development History of Mining TBMs

- Mining TBM construction features **rapid progress, safety, high efficiency, precision, intelligence, and reduced labor requirements;**
- Average advance rates can reach 300-600 m/month, which is **5 - 10 times** that of traditional drilling and blasting methods for rock tunnel construction;
- For tunnel construction > 5 km, construction input costs are comparable to conventional methods, while **safety and quality costs are significantly reduced;**

High degree of digitization

High rock breaking efficiency

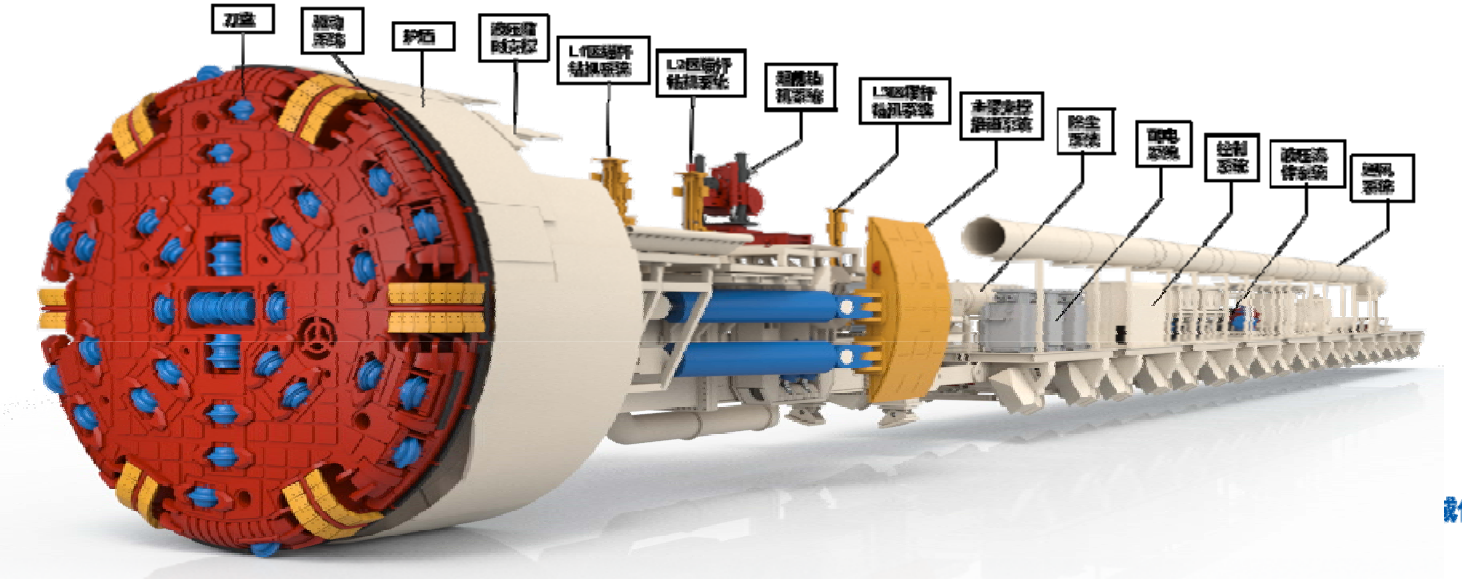


One-pass tunneling completion

Safe excavation

(1) Development History of Mining TBMs

- **Open-type TBM features:** Short shield with telescopic capability, hard rock cutterhead for rock breaking, a single gripper-type main thrust system providing propulsion force, rock bolt and mesh support, small unsupported roof distance, and timely support installation.
- **Technical innovations:** Inverted main beam, ultra-short unsupported roof distance support, simultaneous invert filling and backfilling, integrated drilling and geophysical exploration, etc. Max. monthly advance rates: **812.6 m/month** for inclined shafts, **736 m/month** for horizontal tunnels

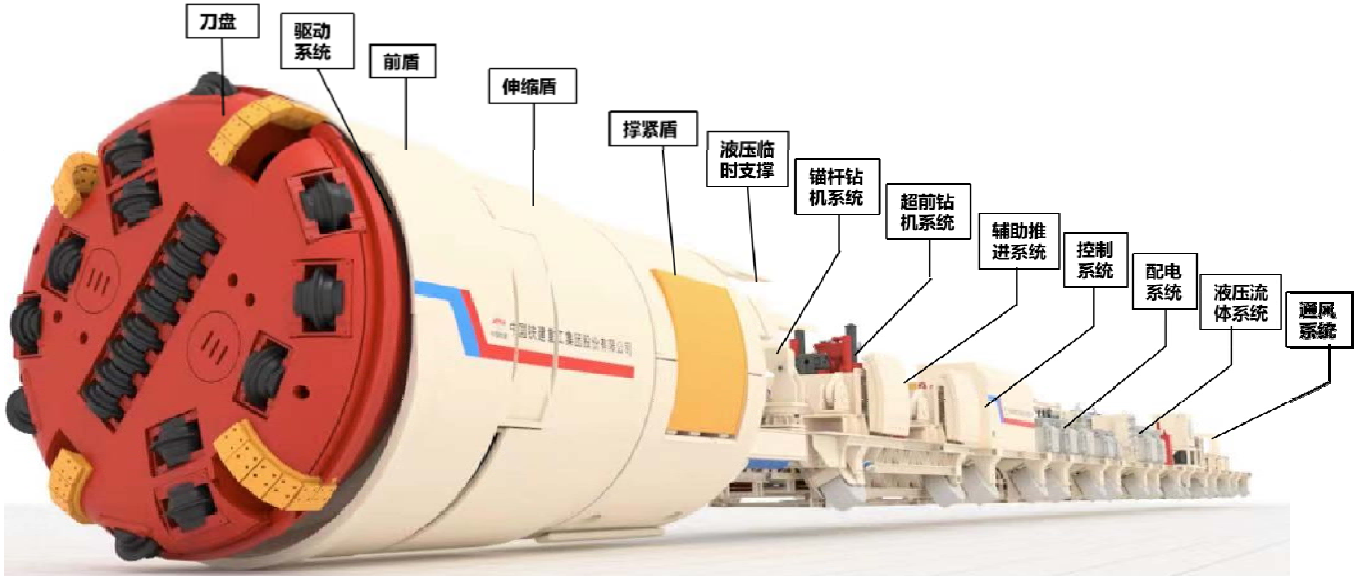


(1) Development History of Mining TBMs

- **Equipment type:** Open-type TBM, excavation diameter 6.33 m
- **User unit:** Shaanxi Zhengtong Gaojiabao Coal Mine
- **Application status:** The largest diameter underground mining TBM in China, total length approx. 5.5 km, rock hardness f=2-6, completed 6° uphill excavation, max. monthly advance of 427 m, now fully breakthrough
- **Existing issues:** Heavy dismantling workload, weak cooling capacity in high-temp environments

(1) Development History of Mining TBMs

- **Double-shield TBM features:** Ultra-small radius turning excavation, continuous steering excavation, ultra-small single-piece segmentation, fully meeting underground transfer and transportation requirements.
- **Technical innovations:** Auxiliary stroke changing, normal support, ultra-small segmentation for shaft lowering, 30 m ultra-small horizontal turning radius, simultaneous invert filling and backfilling, integrated drilling and geophysical exploration, etc. Minimum horizontal turning radius of **R40 m** already achieved in excavation.

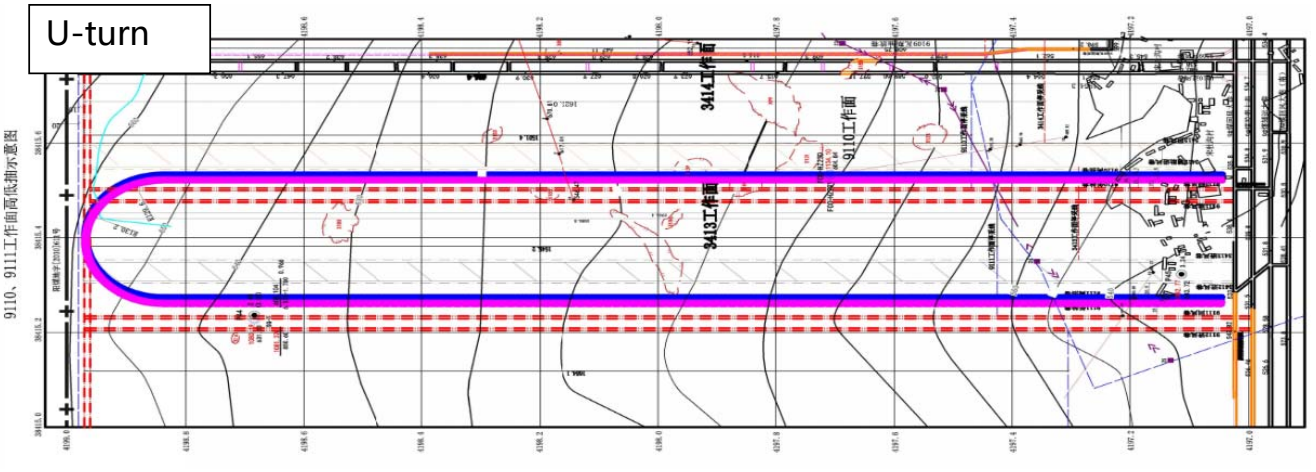


(1) Development History of Mining TBMs

- **Equipment Type:** Open-type TBM，3.63m Diameter
- **User Unit:** Shanxi Lu'an Chemical Xinyuan Coal Mine
- **Application Conditions:** Total length approximately 3.5 km, rock hardness f=4-7, completed horizontal R100 m U-turn construction, maximum monthly advance of 345 m, tunnel fully penetrated

FTA

U-turn



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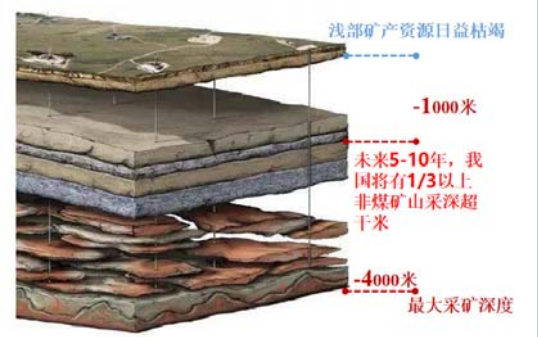
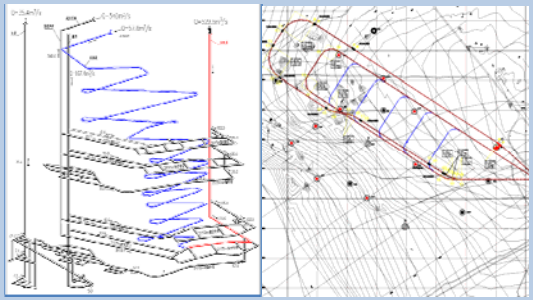
(2) Analysis of Development Pressures for Mining TBMs



01.Deepening

Easily accessible shallow resources - **increasingly depleted**

Mining operations are rapidly extending to deep spaces at **KM-scale depths underground.**



02.Complication

The proportion of complex geological conditions—such as high stress and large deformation of soft rock increasing, posing severe challenges to engineering technology and safety management.

03.Greenization

National "dual carbon" goals and green mine construction requirements impose stringent standards on dust, noise, and energy consumption indicators.

(2) Analysis of Development Pressures for Mining TBMs

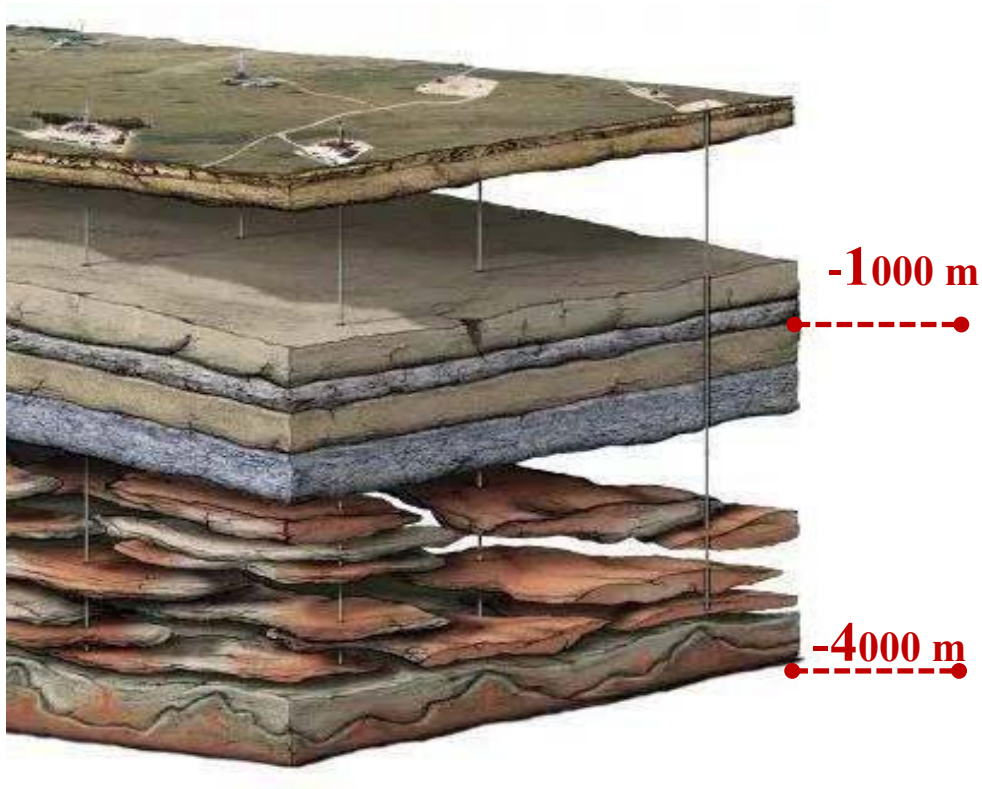
- **Main roadways with long distances:** Such as main haulage roadways, belt conveyor inclines, intake and return air shafts, etc. The length typically needs to be greater than **1.5-2 km** to demonstrate economic feasible
- **Deep high ground pressure mining areas:** Circular cross-sections offer strong compressive resistance, and mechanical excavation provides **high safety.**
- **Mining areas with high environmental requirements:** Such as areas near residential zones or regions with extremely high environmental protection standards where **blasting impacts must be avoided.**
- **Complex geological conditions:** Faults, fractured zones, water inrush, etc., are the main risks for TBM construction. These must be addressed through **advance geological forecasting and enhanced support** (such as timely shotcrete and rock bolting, segmental lining).

(2) Analysis of Development Pressures for Mining TBMs

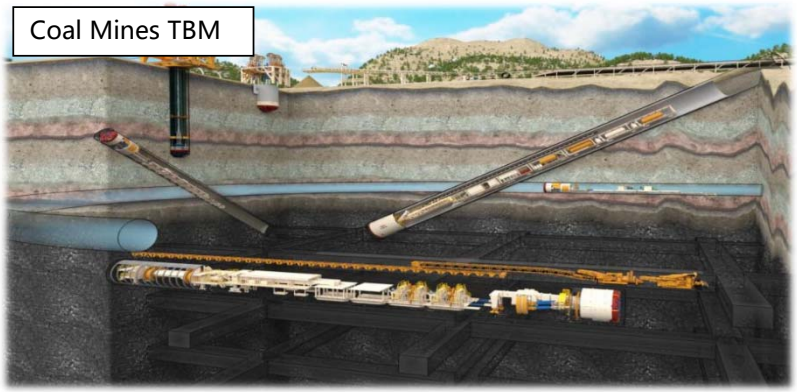
- **Limitations of mine development systems:** Metal ore bodies have variable strike directions, requiring TBMs with **greater flexibility.** Through technological innovation, the industry has developed machines with **ultra-small turning radiues** (R30m-50m) and **large gradients** (-18.1%) to adapt to the development needs of "**following the ore body.**"
- **TBM lowering and assembly:** Due to shaft size limitations in mines, large TBMs often need to be "**broken down into parts**," transported to specific underground chambers via auxiliary ramps or shafts for assembly, placing higher demands on preliminary mine construction.
- **High initial investment costs:** TBM equipment costs and operation-maintenance expenses are far higher than traditional drill-and-blast equipment, requiring **full life-cycle economic evaluation**

(2) Analysis of Development Pressures for Mining TBMs

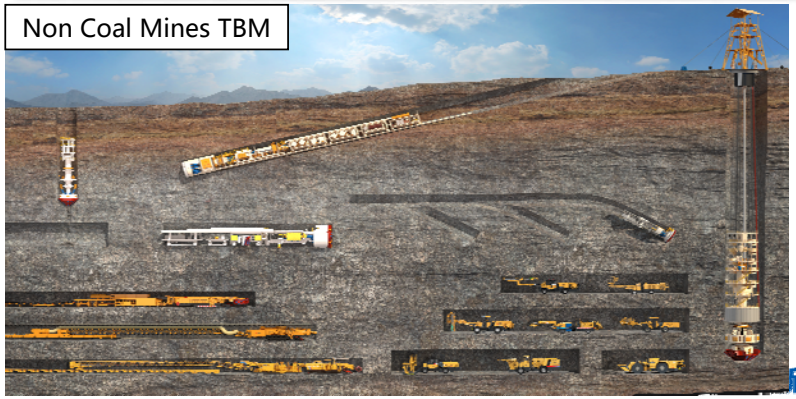
Deepening: As easily accessible shallow resources become depleted, resource development is gradually extending to greater depths. Advances in **equipment and construction methods** are promoting efficient resource extraction.



Coal Mines TBM



Non Coal Mines TBM



(2) Analysis of Development Pressures for Mining TBMs

Complication: Through years of application and development of open-type, double-shield open-type, and shield-type TBMs for mining, the industry still faces the challenges of "**6 Long, 4 High, 4 Many, 3 Large**":

6 Long: equipment length, preparation chamber, manufacturing cycle, assembly duration, dismantling duration, maintenance cycle;

4 High: manufacturing cost, construction cost, personnel quality requirements, maintenance expenses;

4 Many: required personnel,fault points, transfer operations, configuration redundancies;

3 Large: single-piece size, assembly chamber, dismantling chamber.

Large single-piece size

Large assembly chamber

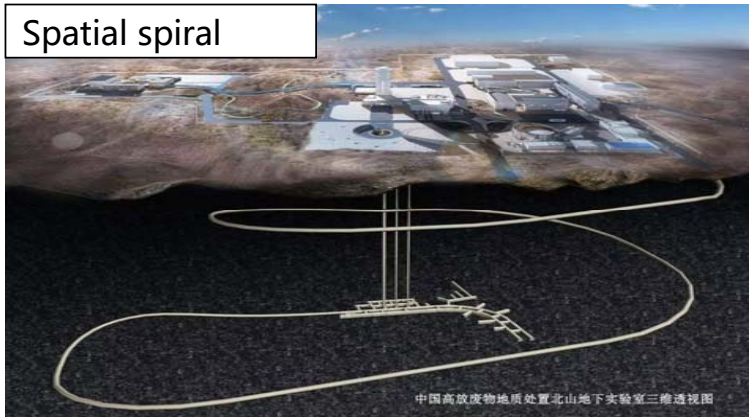
Large dismantling chamber

(2) Analysis of Development Pressures for Mining TBMs

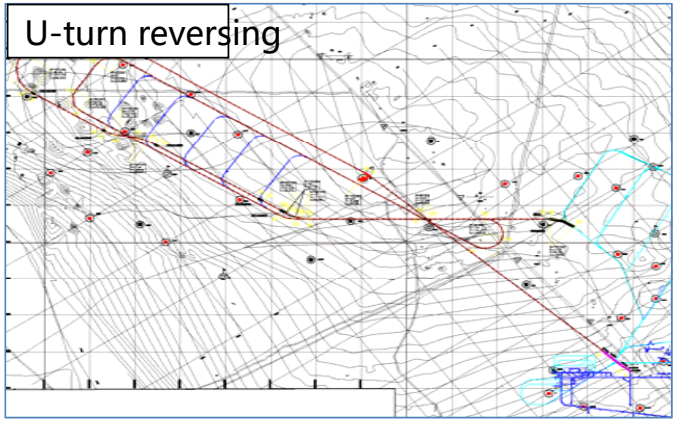
Complication: Through years of application and development of open-type and double-shield open-type, the following engineering challenges remain:

- Seam undulation following: **±25°**
- Complex geology
- Ultra-short distances: Auxiliary roadways **100m+**
- Construction requirements: Safety, intelligence, green, environmental protection, intensification, high efficiency
- Turning with mining district: Ver-**R80m+,** Hori- **R30m+**
- Ultra-long distances: Main roadways **5km+**, Auxiliary roadways **2km+**
- Complex alignment: Spatial spiral, U-turn reversing, vertical S-curve

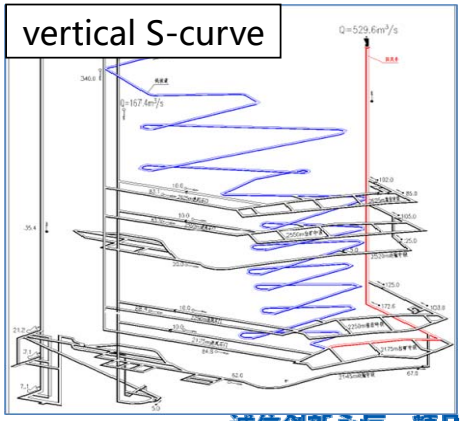
Spatial spiral



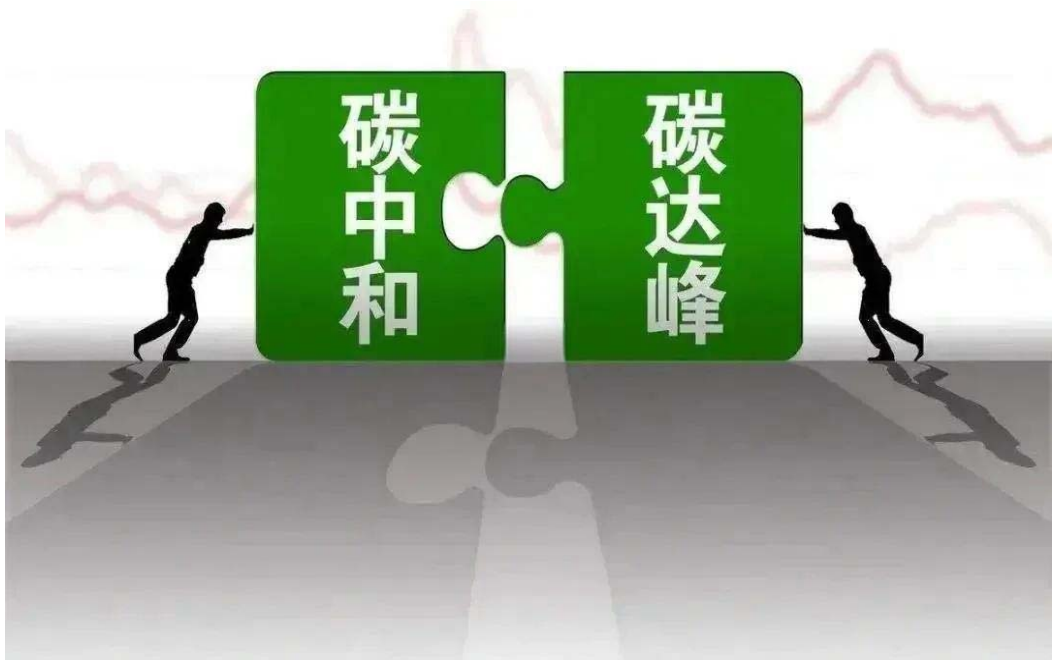
U-turn reversing



vertical S-curve



Greenization: National "dual carbon" goals and green mine construction requirements impose stringent standards on dust, noise, and energy consumption indicators.



Indicator	D&BMethod	TBM
Monthly advance (m)	100-150	400-500
Safety incident rate	High (roof collapse, blasting risks)	Reduced by over 80%
Dust / Noise pollution	Severe (120 dB+)	Low (below 85 dB, dust only 1/10)
Carbon emissions	Moderate	Low
Green mine compatibility	Low	High

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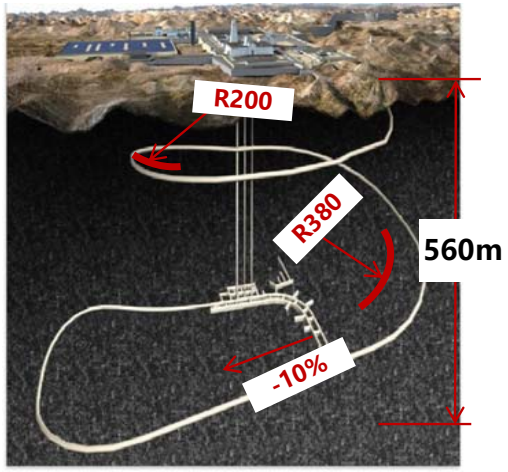
(1) Strong Technical Adaptability

Difficult Challenge Case: Downhill spiral construction faces challenges such as mudstone cutterhead clogging and low slurry removal efficiency under high water inflow.

- Beishan Underground Laboratory Project: the small-radius turning open-type TBM, **Maximum 237 MPa , R250m spiral downhill** cyclic turning (10% gradient).
- **Technical Features:** Adopted **extremely hard rock cutterhead breaking technology** and **spiral small-radius turning** main machine adaptive design.
- **Application Status:** 7 km excavated, max. daily advance of 21.4 m, max. monthly advance of 342 m.

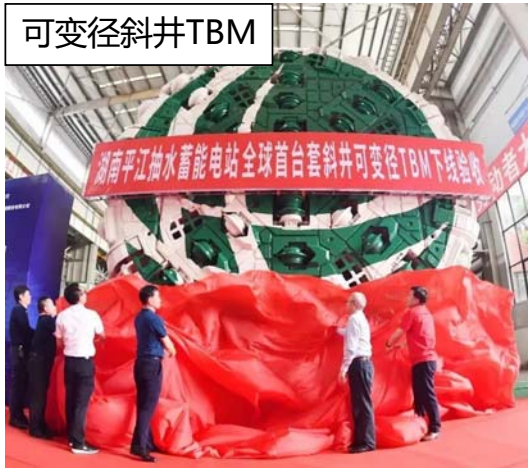


(1) Strong Technical Adaptability

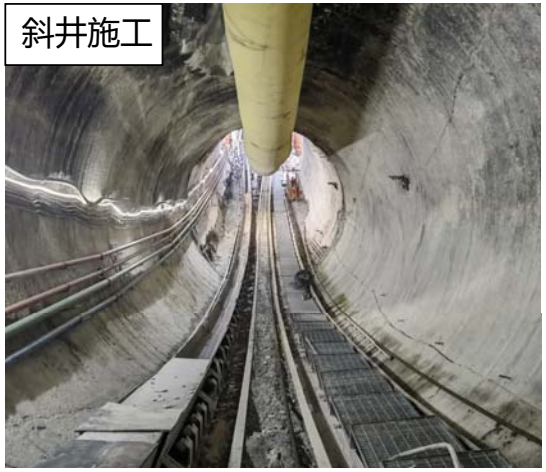
Difficult Challenge Case: Variable-diameter large-gradient uphill construction involves heavy preparation workload, high safety risks, and high construction costs.

- **50° Large Gradient Inclined Shaft:** Lower horizontal tunnel → First-level inclined shaft → Middle horizontal tunnel (diameter change) → Second-level inclined shaft → Upper horizontal tunnel
- R50m Ultra-small Vertical Curve Turning: Horizontal/inclined tunnel transition excavation, diameter variation within **Φ6.5-8m** range, cumulative excavation of 535m, maximum 12m/day. Completed 2 **R50m** vertical curve turns, TBM has entered middle horizontal tunnel excavation.

可变径斜井TBM



斜井施工



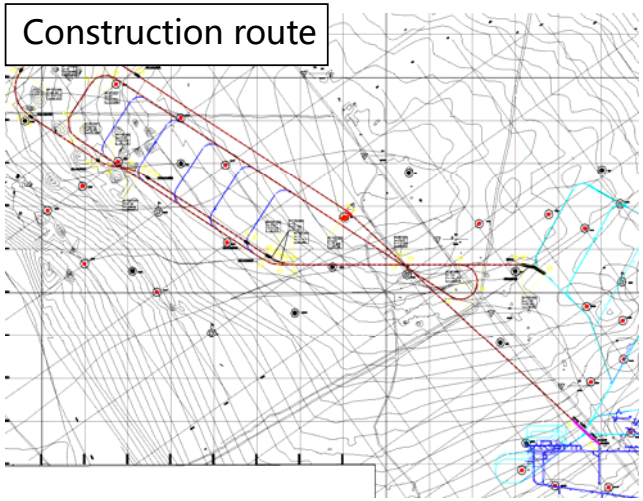
可变径斜井TBM

(1) Strong Technical Adaptability

Difficult Challenge Case: Complex Alignment Construction at Chambishi Copper Mine, Zambia

- **Chambishi Copper Mine, Zambia:** Complex alignment construction, total length approximately 9 km, rock hardness f12-f14, underground cyclic with R50m turning radius;
- **Technical Features:** Open-type TBM, excavation diameter 5.63 m, underground assembly, ultra-small radius turning technology, long-distance hard rock construction technology.

Construction route



Factory acceptance

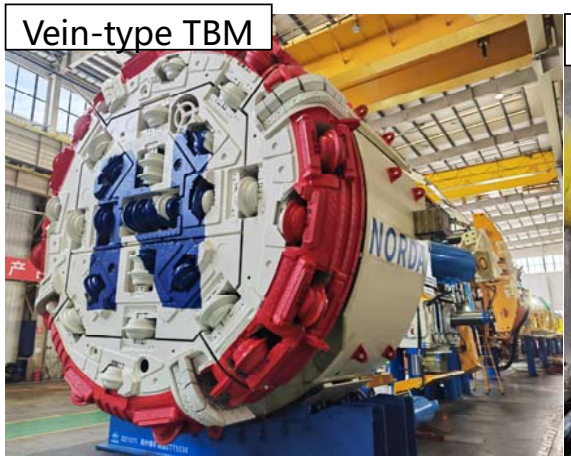
Backups

(1) Strong Technical Adaptability

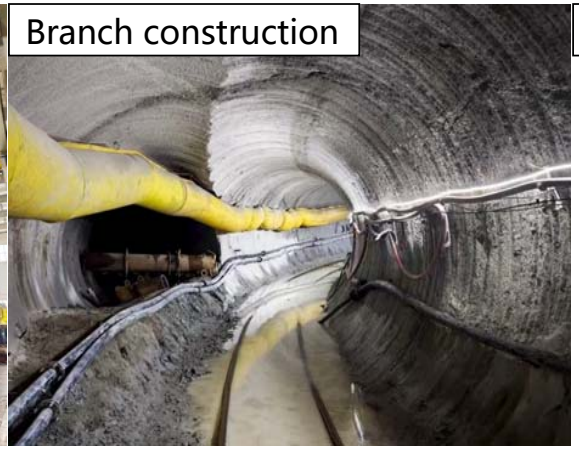
Difficult Challenge Case: Fishbone-type distributed vein alignment construction with frequent retreat and re-launch

- **Small turning radius roadway — Vein-type TBM**
- **Project Features:** Tunnels distributed in fishbone pattern, R100m radius, Y-type alignment with secondary launch, TBM passing through existing roadways, etc.;
- **Technical Features:** Turning radius R100m, large-range shield telescoping technology, active steering at front end of support main machine.

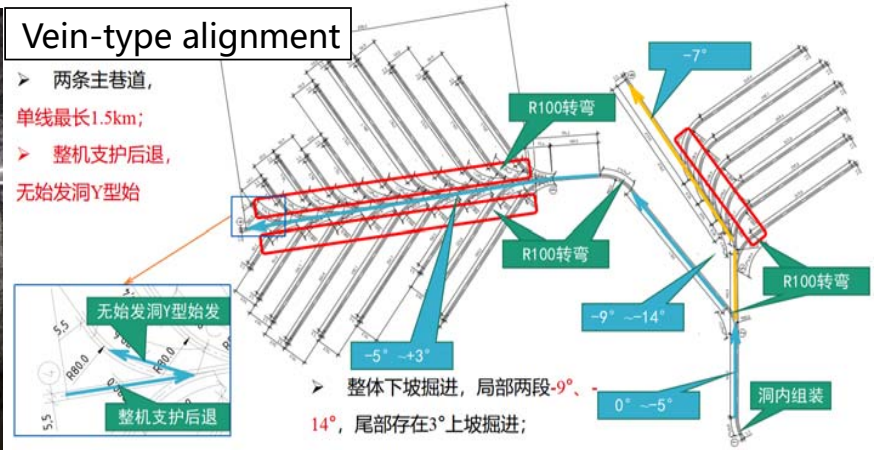
Vein-type TBM



Branch construction



Vein-type alignment



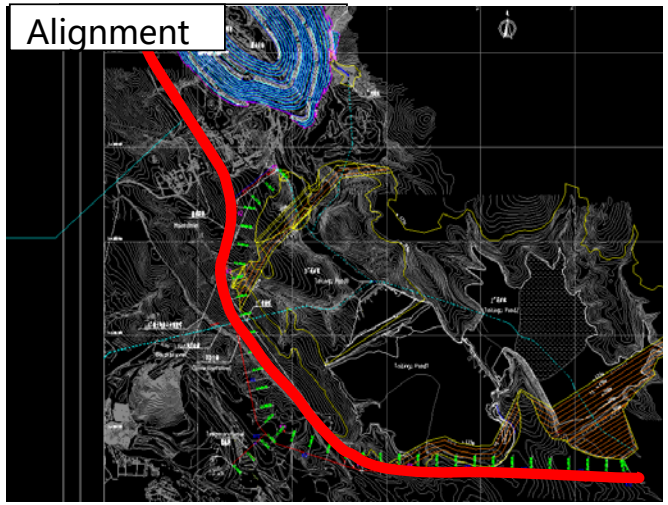
(2) Significant Economic and Engineering Value

Serbia Zijin Mining VK Mine Project

□ **Application Status:** Double-shield TBM, excavation diameter 5.49 m, total length **approximately 8.3 km**, rock hardness f4-f10, with costs comparable to D&B methods, achieved breakthrough **4 months ahead of schedule**, with max. monthly advance of 845 m.

□ **Follow-up:** New projects have already been secured. Plans to repair and retrofit the equipment for construction of a 4,300 m tunnel, further improving economic efficiency.

Alignment



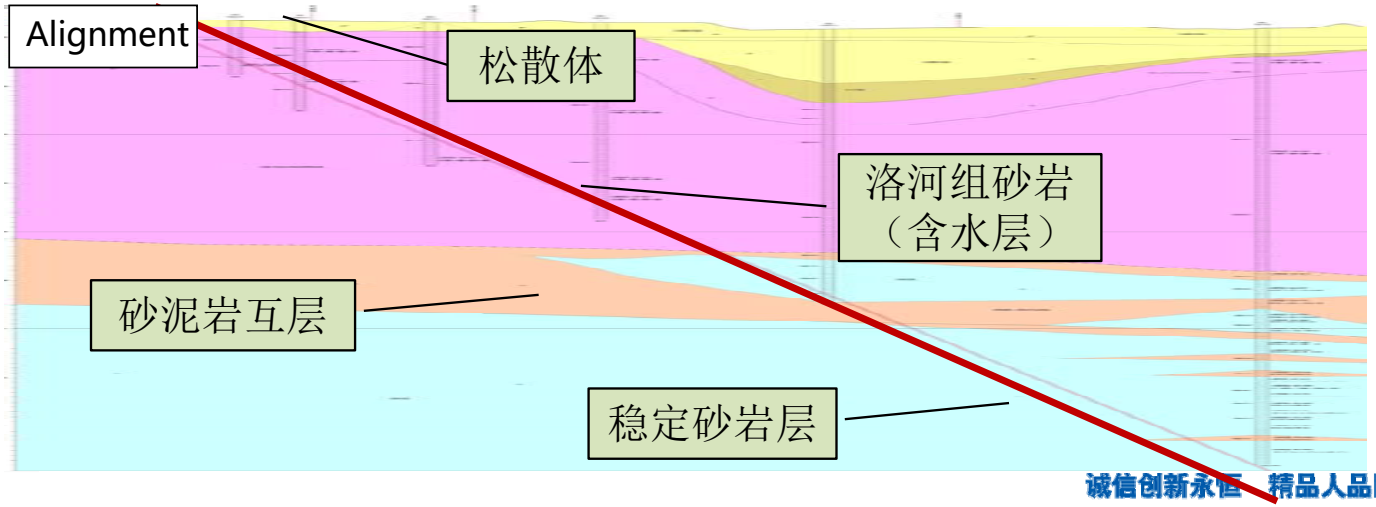
Assembly completed

launching

(2) Significant Economic and Engineering Value

Yanchang Petroleum Kekegai Coal Mine Project - Main and Auxiliary Inclined Shaft Engineering

- Two tunnels for main and auxiliary inclined shafts, single line length of 5.3 km each, gradients of -5.6°/-6°. Technologies including **simultaneous invert block paving**, long-distance **uphill drainage**, and **continuous synchronized support** were employed, setting a national record of 812.6 meters in the coal industry. TBM achieved breakthrough **6 months ahead of schedule**, with project cost savings of over 2 billion RMB, realizing early revenue exceeding 100 billion RMB.
- The two machines were subsequently redeployed to another **two projects with the length 5.4 km and 7.8 km** respectively, further reducing construction costs.



Thank you!

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