Urban Tunnelling for Sustainable Development

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Contents

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Tunnelling Updates in China

Overview of tunnelling over past 30 years in China—Traffic Tunnels

Type	*Length (km) by 1990*	*Length (km) by 2023*	*Increase (times)*	*Completed (km) in 2023*
Railway tunnel	2,359	23,508	10	1,292
Highway tunnel	130	29,460	226	2,290
Metro	54	8,547	158	541
Total	2,543	61,515	24	4,123

Overview of tunnelling over past 30 years in China—Traffic Tunnels

Metro systems contribute to sustainable cities

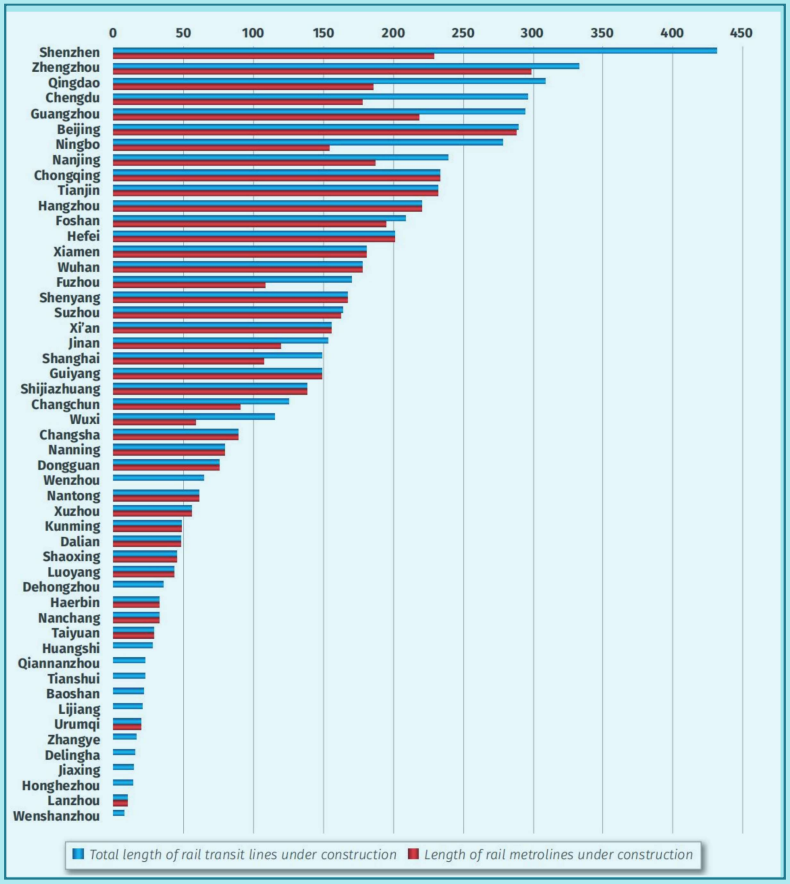
- ***Metro systems: backbone of urban transport in many major cities due to their:***
  - ***Large transport capacity***
  - ***Speed, punctuality, and safety***
  - ***Environmental friendliness***

    reduce greenhouse gas emissions,

    increase energy efficiency,

    reduce air pollution,noise...
  - ***Development of transit-oriented developments (TODs)***

Metro under Construction by Cities in China



By the end of 2022

- ✓ **51 cities** building metro lines, with a total length of **6,359km**.
- ✓ **22 cities** building **5 or more lines** at the same time

Source :CHINA ASSOCIATION OF METROS

Shared bicycles covering the last kilometer between metro stations and final destinations.

--convenient and green

Achievements of Metro Construction over 3 decadess in China

- *Massive Expansion: Mileage growth, city coverage.*
- *Vast Experience: Different methods in varied conditions.*
- *Significant Innovations: new methods, equipments, materials, as well as intelligent technologies*
- *Rapid Construction: completed within 5 years.*

To alleviate congestion & environmental issues, to ensure social fairness, and increase efficiency.

Experiences can be shared.

2

Challenges of Tunnelling in Urban Areas

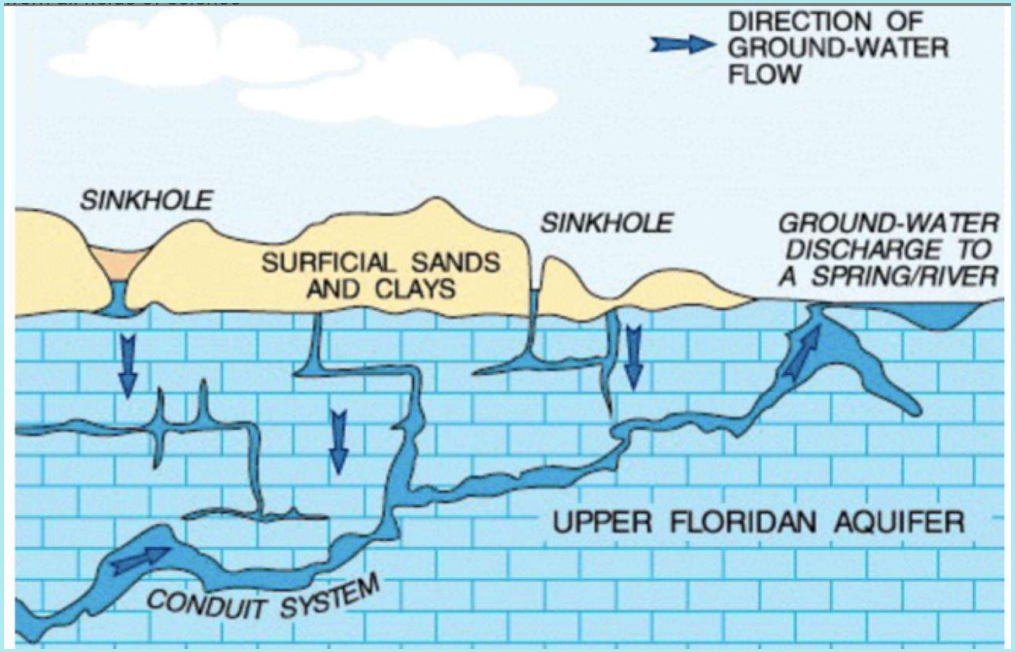
Challenges of Urban Tunnelling-Limited space

- **Limited space**
- limited ground space for access to tunnelling
- limited underground space for tunnels

Image credit: Pexels / Sergio Souza

Challenges of Urban Tunnelling-Complex Geology

- **Complex ground conditions**
- Shallow depth
- Soft upper layer and hard lower rock
- Complex geology (Karst, gas bearing, high groundwater table)



Source: Kratz and DeHan 1996

Challenges of Urban Tunnelling-Sensitive Surrounding

- **Sensitive Existing Infrastructure**
  - *Nearby Buildings and Structures*
  - *Utilities and Services*
- **Environmental and Social Risks**
  - *Noise and Vibration*
  - *Dust and Air Quality*
  - *Excavated material treatment*

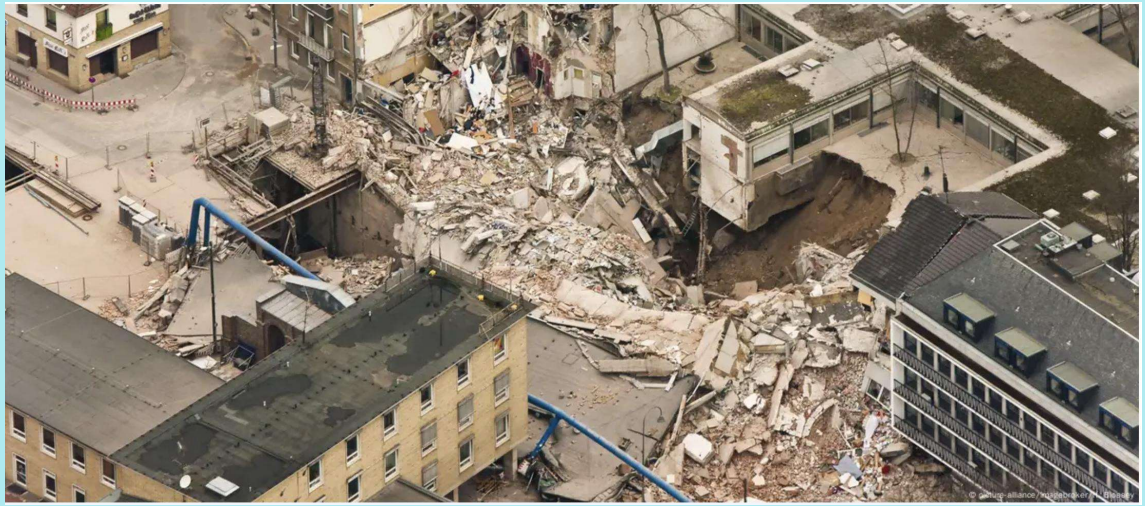


Image: picture-alliance/imagebroker/H. Blossey

Challenges of Urban Tunnelling-High Risks

➢**High safety and loss risks**

- *Personnel safety*
- *Project safety*
- *Surrounding facility safety*
- *Big financial loss in case of failure*

3 Innovations in Urban Tunnelling

3. Innovations in Urban Tunnelling

3.1 - Multifunctional Urban Underground Space

3.2 - Prefabricated and Assembled Metro Stations

3.3 - Innovations of Mechanized Tunnelling in urban areas

3.4 - Geology Prediction during Tunneling

3.5 - Environmentally Friendly Construction

3.1 Multifunction of Urban Underground Space

- ✓*The space in urban areas is limited on both the ground and underground.*
- ✓*Multifunction is one of the solutions.*
- ✓*Example: Integrated Transit Hub Station of Shenshen Metro Line 14*

Ground situation before the construction of Huangmugang Metro Station,Shenzhen

Integrated Huangmugang Station of Shenzhen Metro Line 14,China

Before

- *Complicated road condition*
- *Four-level overpasses, resulting in the separation of urban functions*
- *Unfavorable surrounding environment*
- *Inaccessible by public transport*
- *Inconvenient for pedestrians*

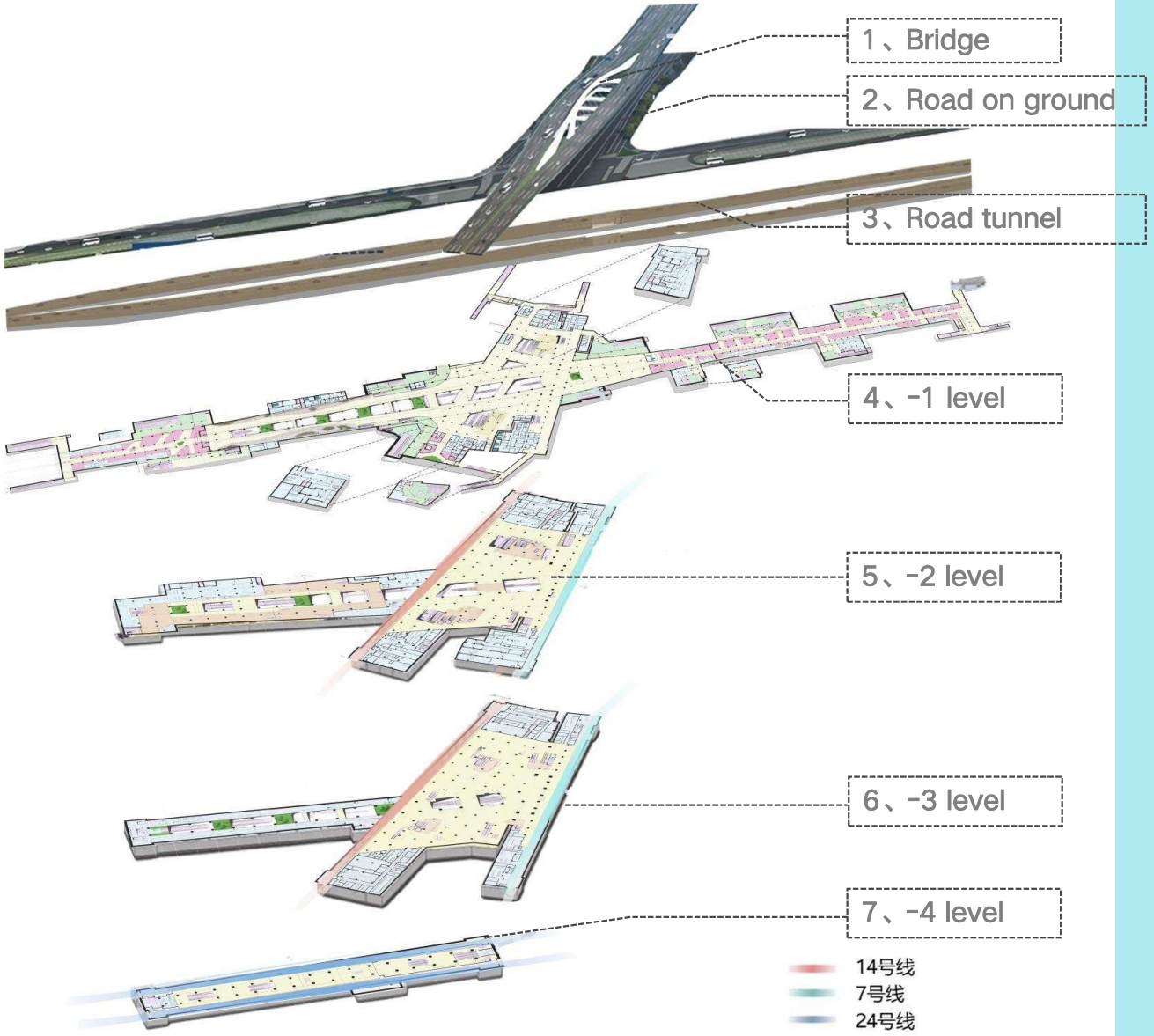
traffic reorganization

After

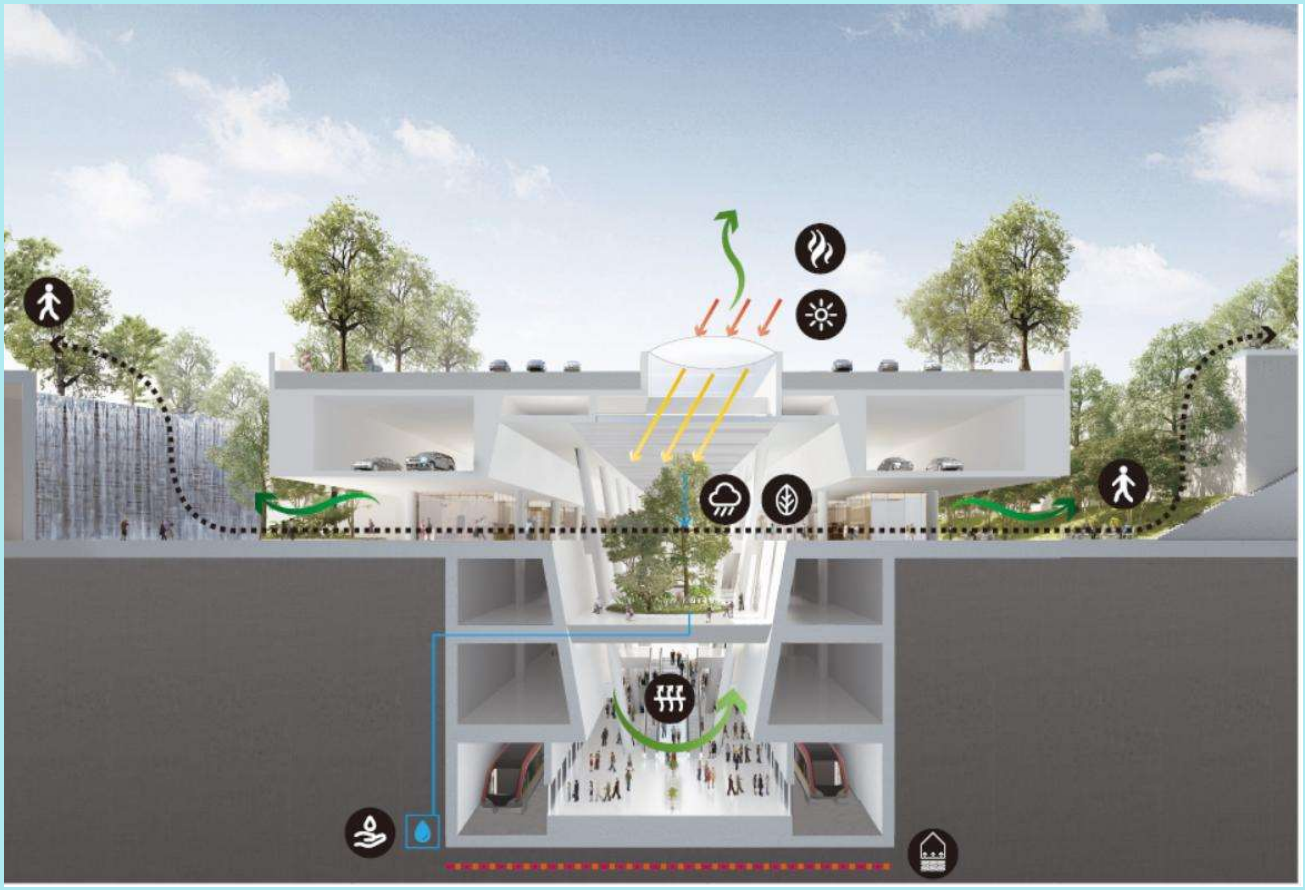
- *Integrated traffic hub · Urban living room*
- *"one bridge and one tunnel",*
- *Free ground space and increased green plants*
- *Connected with the bus + slow travel at plazas*
- *The plazas at 4 corners improve the connectivity of the surrounding area*
- *Stimulate urban development*

Integrated Traffic Hub

- ***Combined the bridge, the tunnel and the metro station into one system, making efficient use of urban space.***
- ***Interchange metro station for 3 metro lines(Line 14, 7 and 24),***



V Column Structure & Sustainable Design

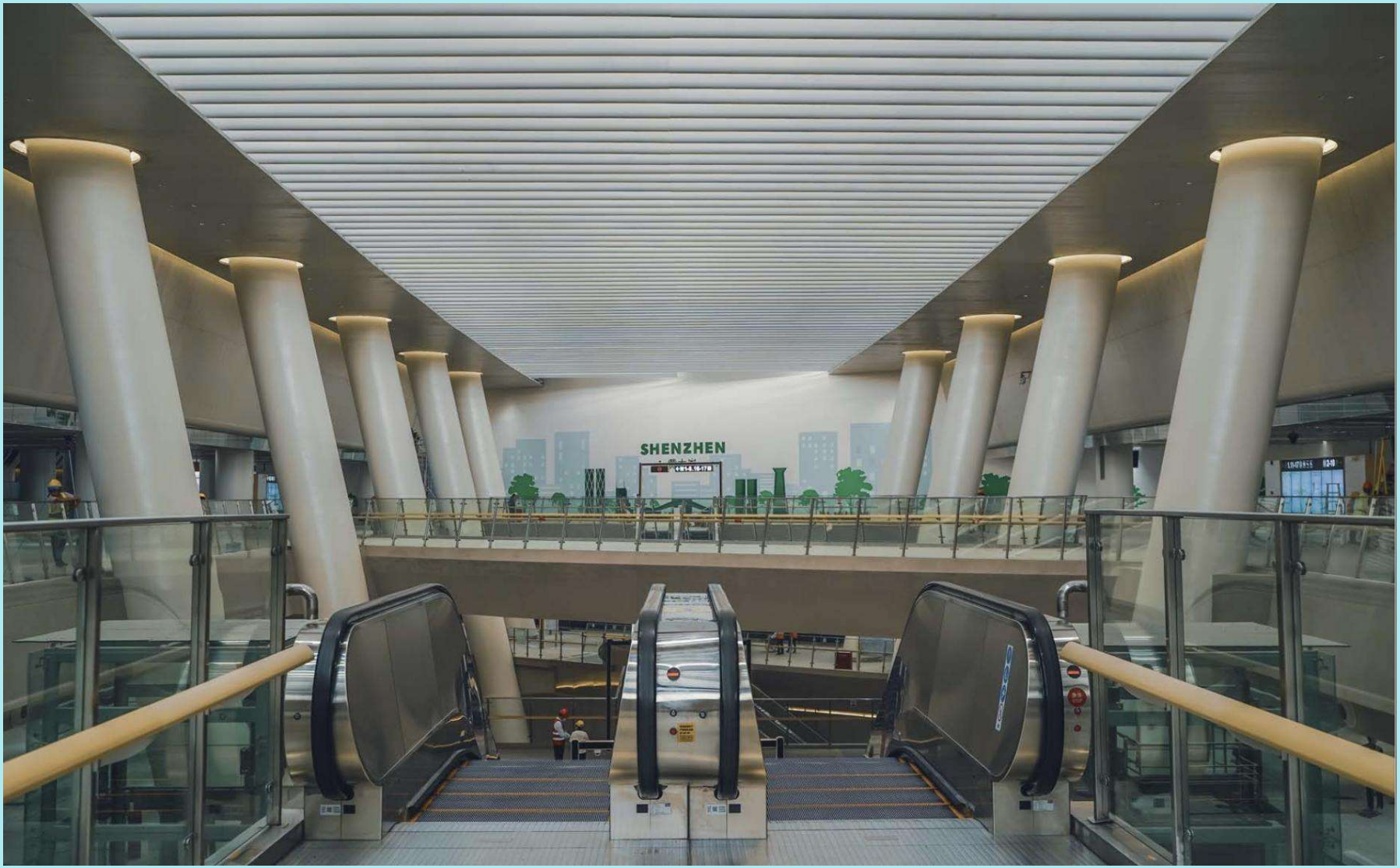


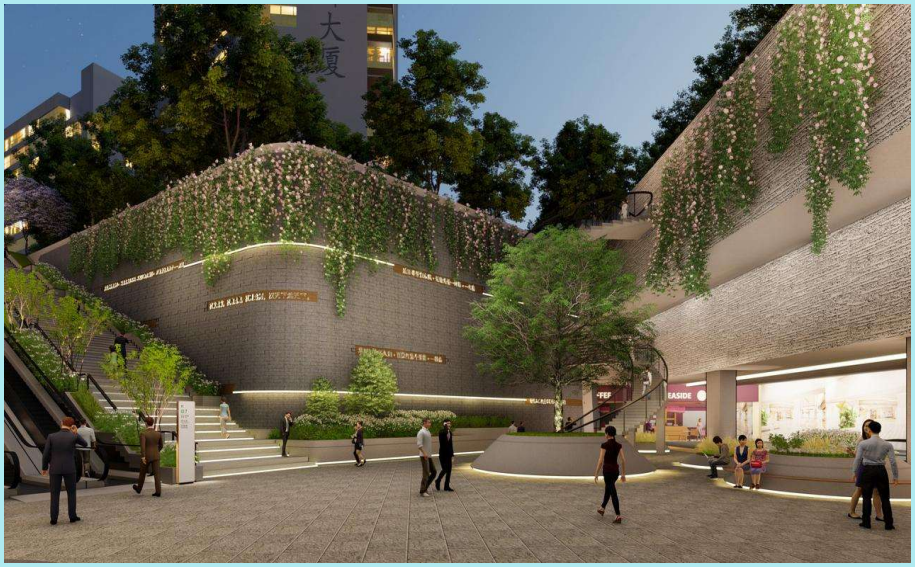
Connectivity: The plazas at 4 corners improve the connectivity of the surrounding area

Natural lighting： By the skylight, the underground space is as bright and comfortable as the ground

Natural ventilation through the skylight and 4 plazas

Rainwater is used for plant growth

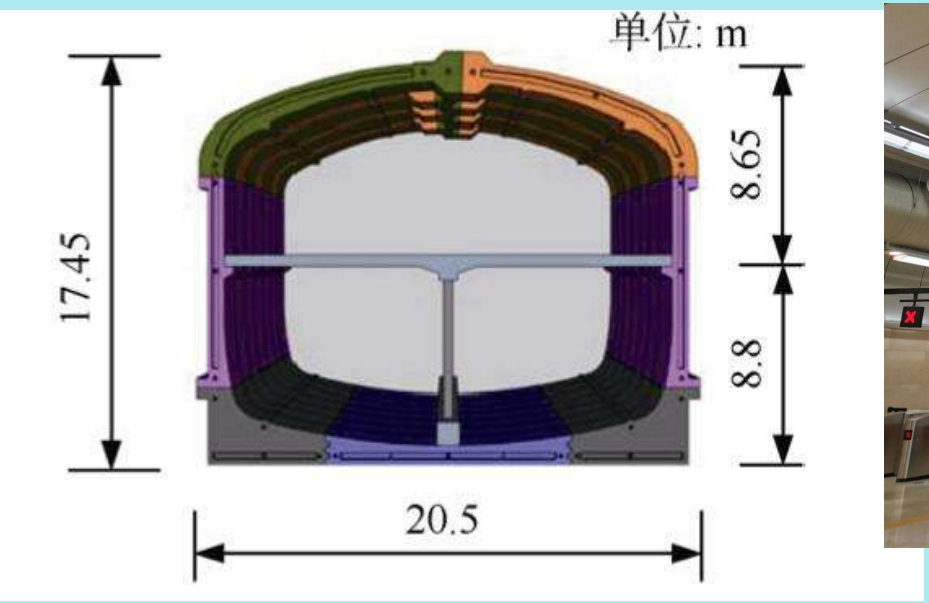

SHENZHEN


大厦

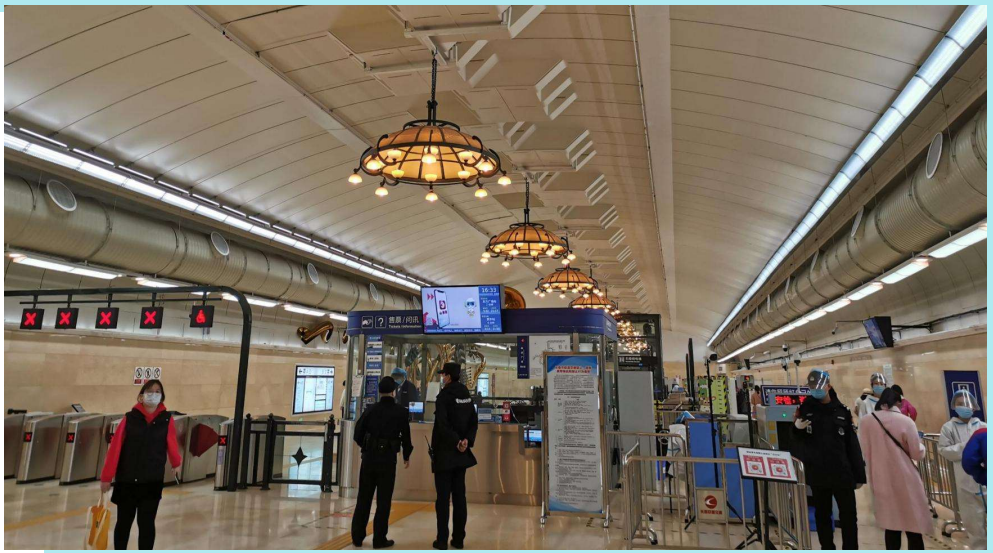
3.2 Prefabricated and Assembled Metro Stations

- *Challenges of the industry: lack of experienced workers*
- *Related to cost, safety and quality issues.*
- *China encourages greater use of prefabricating and assembling technologies for infrastructure.*

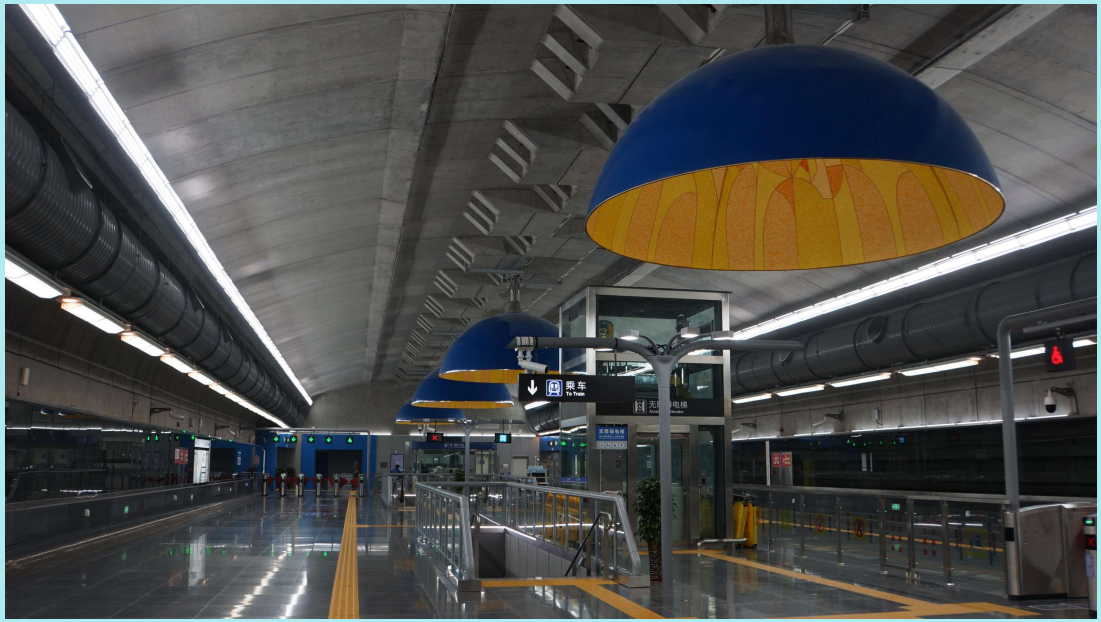
Prefabricated and Assembled Metro Stations



A Prefabricated station: each ring with 7 segments, 2m wide

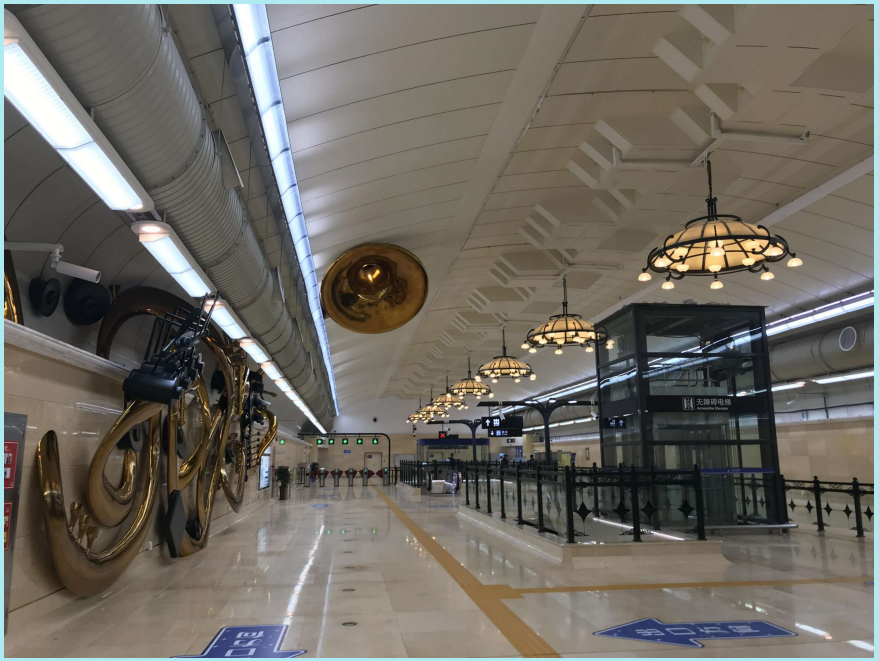


Jianshe Square station of Changchun Metro Line 2 in operation



Shuangfeng Station of Changchun Metro Line 2 in operation

Jianshedajie Station of Changchun Metro Line 2 in operation



Advantages of the Prefabricated and Assembled Method

- Created originally for cold weather
- Also proved useful in a variety of other situations
- Innovation of a whole process, including design, prefabrication, assembly and other aspects, ,such as watertightness.

Advantages:

- Less labor intensive
- less construction waste
- better quality
- faster construction

Used for more than 30 metro stations in both northern and southern cities

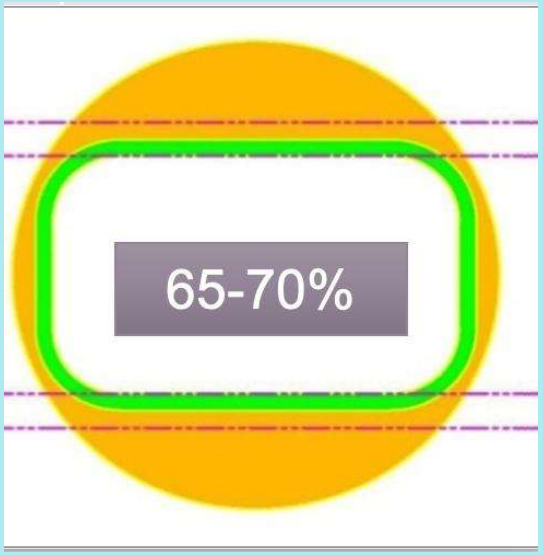
3.3 Innovations of Mechanized Tunnelling in Urban Areas

Non-circular TBM Shapes for Limited Underground Space

To cope with this challenge of** limited underground space**, different shapes of TBM have been developed and used:

- ✓***Rectangular TBM***
- ✓***Quasi rectangular TBM***

Rectangular Tunnels



Rectangular tunnel section:
-- 65-70% cut;
-- 30-35% saved

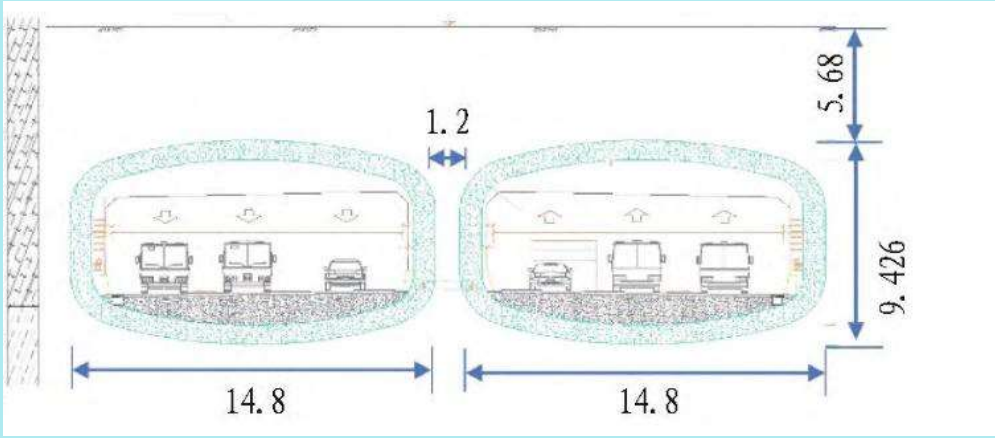
Rectangular tunnels compared to circular tunnels are good at:
- ✓ *efficient use of space*
- ✓ *better use of tunnel volume*

Especially valuable for multiple-lane road tunnels

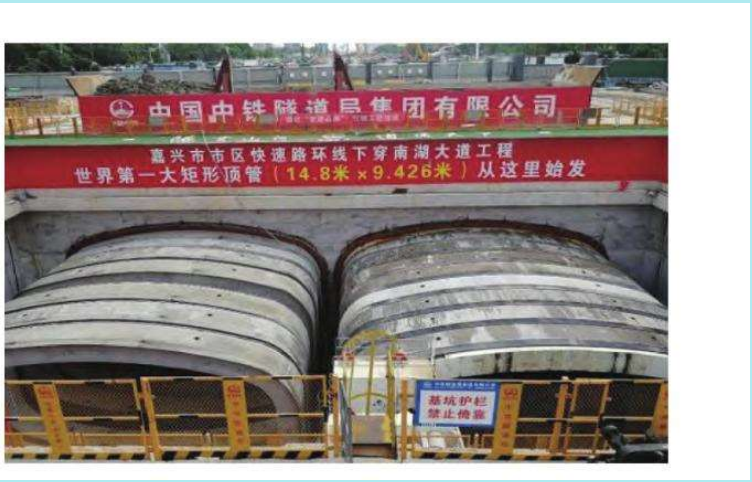
But it needs:
- ➢ *more effort to handle unfavourable structure stress*
- ➢ *suitable rectangular TBMs/PJMs*

15m Wide Rectangular Pipe Jacking Machine used for Nanhu Avenue Tunnel, China

EPB Machine

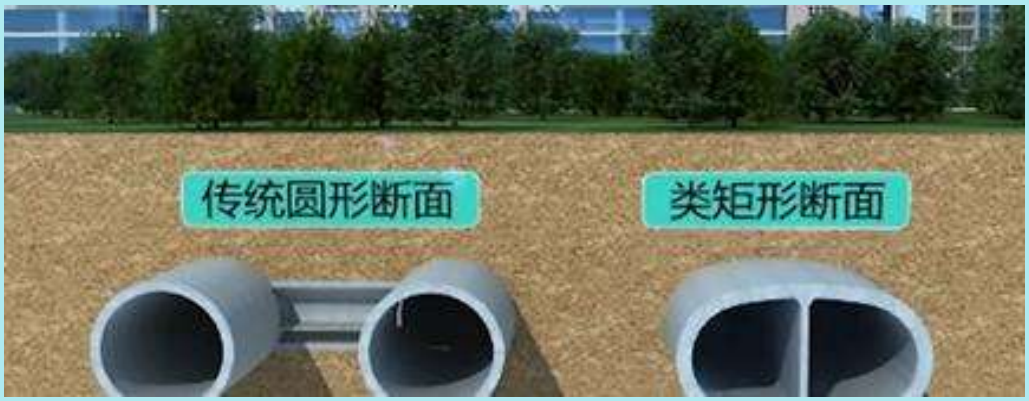


Tunnel: 100.5m long, six lanes in two directions



Construction:
Machine manufactured on June 18, 2020,
Tunnel completed on October 21 2020.

Quasi Rectangular TBM



Twin tubes commonly used for metro projects.

Usually, 18m or more spacing required for structure safety reasons, but not available in some urban areas.

Quasi-rectangular TBM is a solution.

Compared with the traditional twin-tube method,

- *Nearly 40% of the underground space horizontally saved*
- *35% of that in the vertical direction*

Quasi Rectangular TBM

The first application in China: two running tunnels of Ningbo Metro Line 4 in 2016.

The quasi rectangular TBM： 11.5m wide ×6.937m high

Have used for around 20 metro projects for in Ningbo , Shanghai and zhenzhou.

3.4 - Geology Prediction during Tunnelling

Why is Geology Prediction Important for Urban Tunnelling?

- *1. Risk Mitigation*
- *2. Protection of Existing Structures (foundations)*
- *3. Ensuring Safety of tunnelling*
- *4. Optimizing tunnel construction*

New Requirements on Geology Prediction System for Tunnelling by TBM

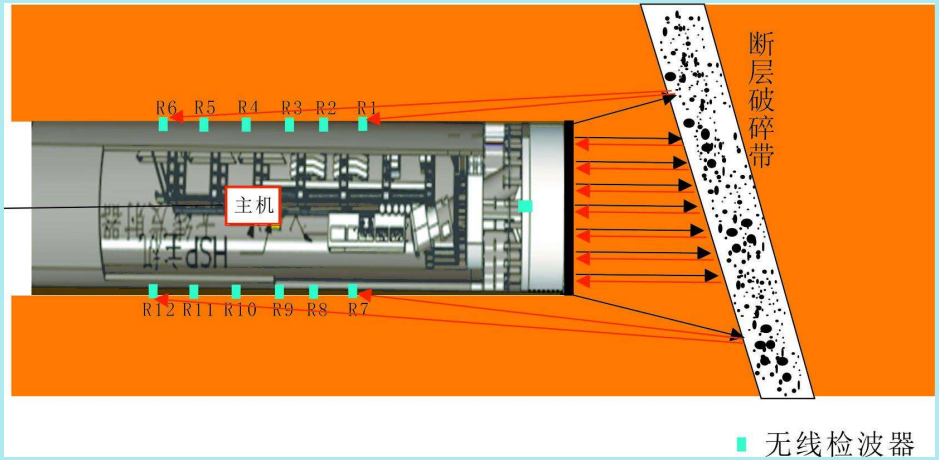
Features of TBM tunnelling:

- ☐Excavation face cannot be seen
- ☐TBM operates automatically
- ☐Fast advance rate
- ☐Sensitive to geology changes
- ☐……

New requirements on geology prediction system for TBM tunneling:

- ✓Long distance
- ✓Accurate result
- ✓Rapid prediction.
- ✓……..

HSP-T geological prediction system for TBM tunnelling



HSP-T法探测方案

Prediction scheme of HSP-T method

wireless dector

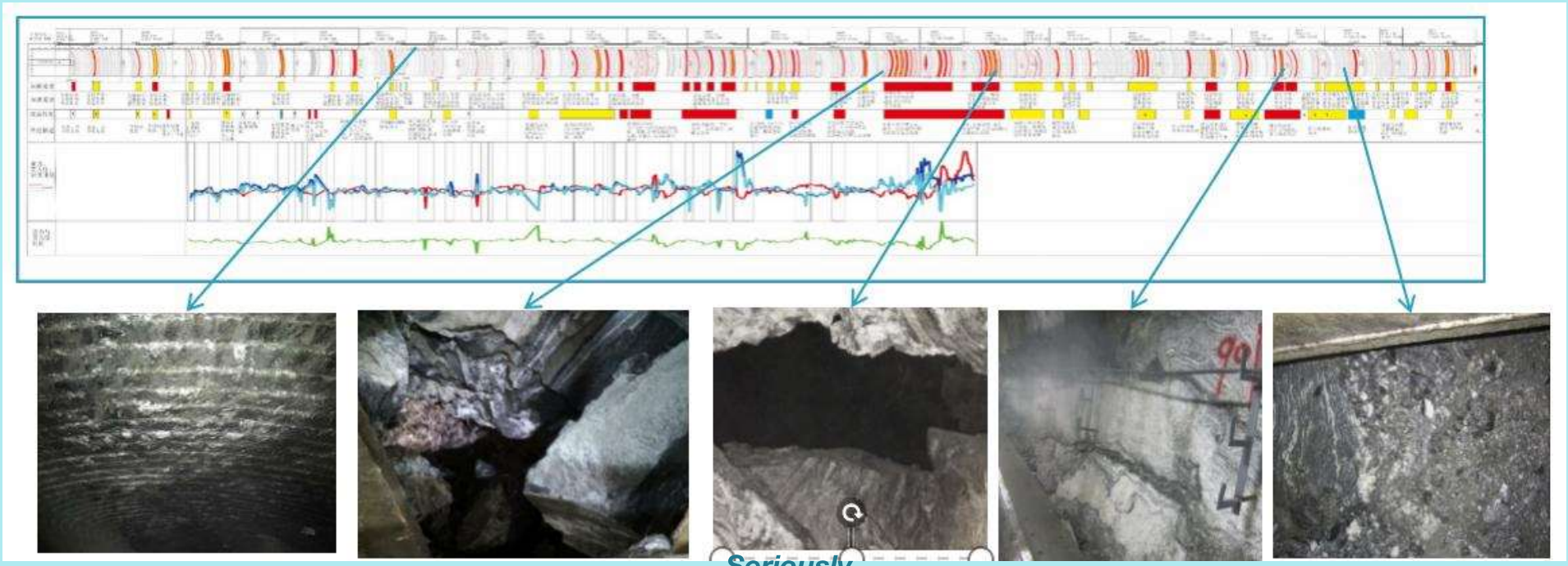
Features of HSP –T system:

- Use vibration of TBM cutting rock as seismic source signal, no sensors required and installed
- No influence to TBM boring
- Short measuring time (25 minutes)

- ✓ Independent system from TBM
- ✓ without any sensor installed in cutterhead
- ✓ Suitable for different TBMs: Open TBM, Double Shield, Single Shield, EPB
- ✓ Wireless transmission technology

Patented by China Railway Academy Co.,Ltd.

Application to Double Shield TBM



Intact rock

Fractured rock

Seriously fracturaed rock

Soft ground with water

Moderately fractured rock

3.5 Environmentally Friendly Construction

(use of excavated materials)

Challenges of Handling Slurry/EPB TBM spoil in Urban Areas

- ☐ *Spoil difficult to handle*
- ☐ *Special transportation vehicles required*
- ☐ *Distance from the tunnelling site*
- ☐ *Large dumping landfill required*
- ☐ *Unstable and risky to the environment*

Innovative Spoil Treatment Technology and Equipment

☐ Treatment flow
Separation and dehydration

Aggregates

Sand

Water

Clay

☐ Reuse of treated spoil

Gravel and Sand

Clay

Water

Application of the Technology and Equipment

- ✓*The application started in Shenzhen in 2019.*
- ✓*The equipment has been improved greatly, which is more compact, more efficient and more cost-effective.*
- ✓ *It has been used in many other cities in China.*

4 Conclusion

Conclusion

1. *Urban tunnelling contributes to sustainable development by reducing traffic congestion, lowering pollution, and increasing efficiency.*

2. *However, tunnelling in urban areas presents challenges due to limited space, complex geology, and sensitive surroundings, which require continuous innovation.*

3. *Innovations in urban tunnelling play a crucial role in optimising urban space, ensuring construction safety, and minimising environmental impact.*


Thank You !