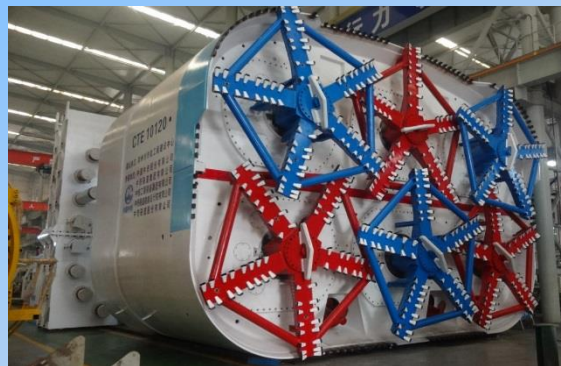




Underground pedestrian passage under Heiniucheng Road in the New Badali area in Tianjin

-- Key technologies of super-large section rectangular pipe
jacking construction



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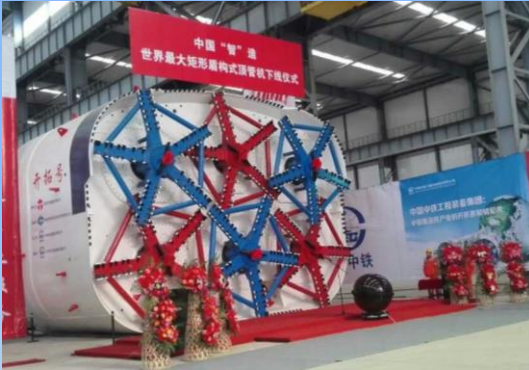


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Project summary



Underground passage under Heiniucheng Road in the New Badali area in Tianjin



The underground passage under Heiniucheng Road is a pedestrian passage, but it also serves as a comprehensive pipe gallery for the city's underground pipelines to pass through the Heiniucheng Road -- a trunk road in the city. The passage is 92.6m long, and the cover soil is 8.17m thick. The tunnel was constructed by pipe jacking method. The pipe sections are made of C50P12 reinforced concrete, and have a width of 1.5m and a thickness of 700mm. The number of pipe sections is 62, the weight of a single pipe section is 77.2t. The size of the structural section is 10.42m×7.55m, making it the largest cross section in the world. It is the first time a super-large section rectangular pipe-jacking tunnel was built in the watery and weak strata in Tianjin. Therefore, there was no similar experience that can be used for reference. During the construction of this project, we have overcome many technical difficulties such as dynamic waterproofing of the tunnel door in the jacking process of each pipe section, attitude control of the pipe jacking machine and pipe sections, high-precision prefabrication of pipe sections in extremely cold weather, and deformation control of the ground surface and pipelines.

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China Coal Handan Construction Supervision and Consulting Co., Ltd.	Sun Jifeng	China

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Part I Advantages of pipe jacking construction



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→ 1. Differences between pipe jacking method and shield method

Similarities

- 1) They are both subsurface excavation methods;
- 2) Work shafts (wells) must be excavated, and the construction methods of the work shafts (wells) are the same;
- 3) The excavation method of the working face is similar, and the construction techniques at the beginning and end of the tunnelling process are basically similar;
- 4) Both involve such issues as seam waterproofing and surrounding environmental protection.

Differences

Shield method

The segment is assembled in the tail of the shield, and the segment is fixed.

The propulsion cylinder is inside the support ring of the shield machine and moves synchronously with the shield machine.

Pipe jacking method

After the pipe section is assembled, it moves forward synchronously with the tunneling surface.

The jacking cylinder is fixed in the launching shaft.

→ 2. Advantages of super-large section rectangular pipe jacking

1) The construction area is small; the interference to the city is small; the urban traffic is not blocked; there is no need to relocate pipelines; and the impact on the ground environment is small. Therefore, the project has realized civilized construction.

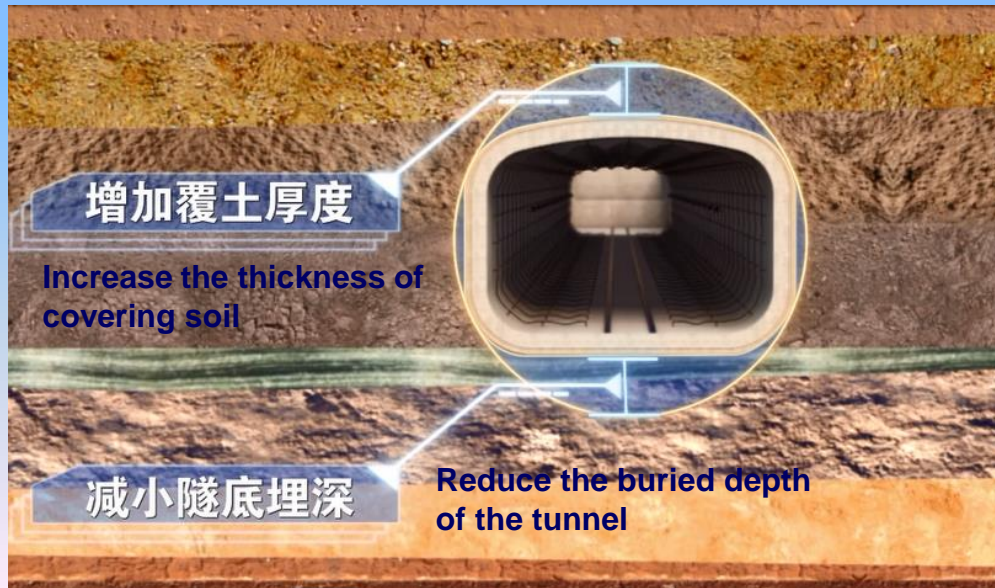
2) Various types of cross-sections make it suitable for construction of structures with various forms of sections.

3) It has low comprehensive cost and short construction period.



→ 3. Advantages of super-large section rectangular pipe jacking

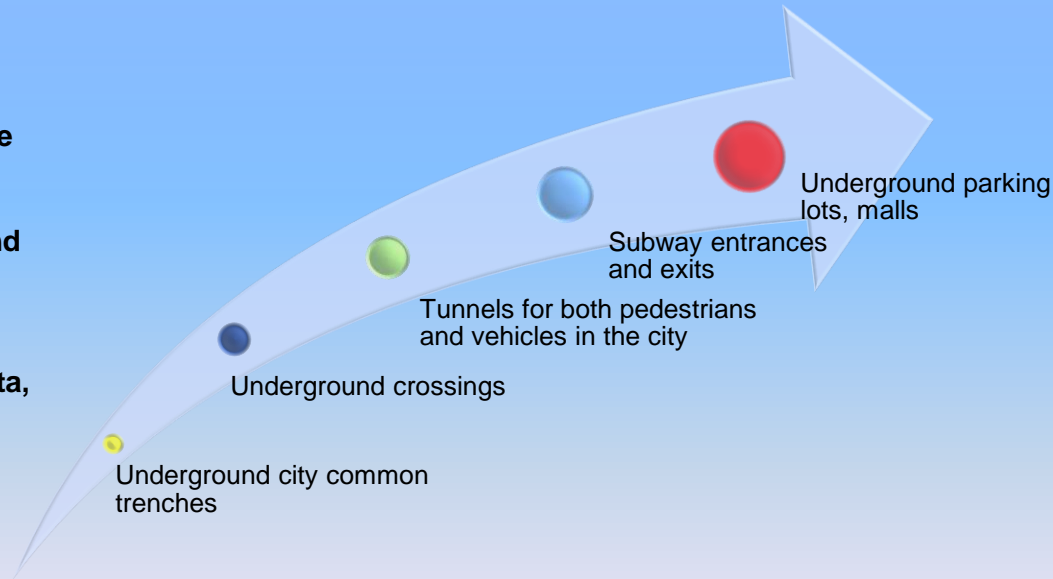
When a circular section and a rectangular section have equal effective space, the rectangular section can save more than 35% of underground space than the circular section, and can greatly reduce the buried depth of the tunnel and increase the thickness of the covering soil, thereby saving construction investment cost and reducing safety risks of construction .



→ 4. The scope of application and prospect of super-large section rectangular pipe jacking

1) It has been widely used in construction of underground pipelines in China, such as underground passages, underground water supply and drainage pipelines, power cables, underground pipe network common ditches, gas passages and communication pipelines. It has also been used for construction of underground pipelines that pass through special sections of roads, railways and rivers.

2) It is applicable to silty sand or sandy soil in saturated water-bearing strata, muddy clay, clay, and also applicable to construction under combined geological conditions of general rock formations.





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Part II Introduction to the underground passage project under Heiniucheng Road in Tianjin

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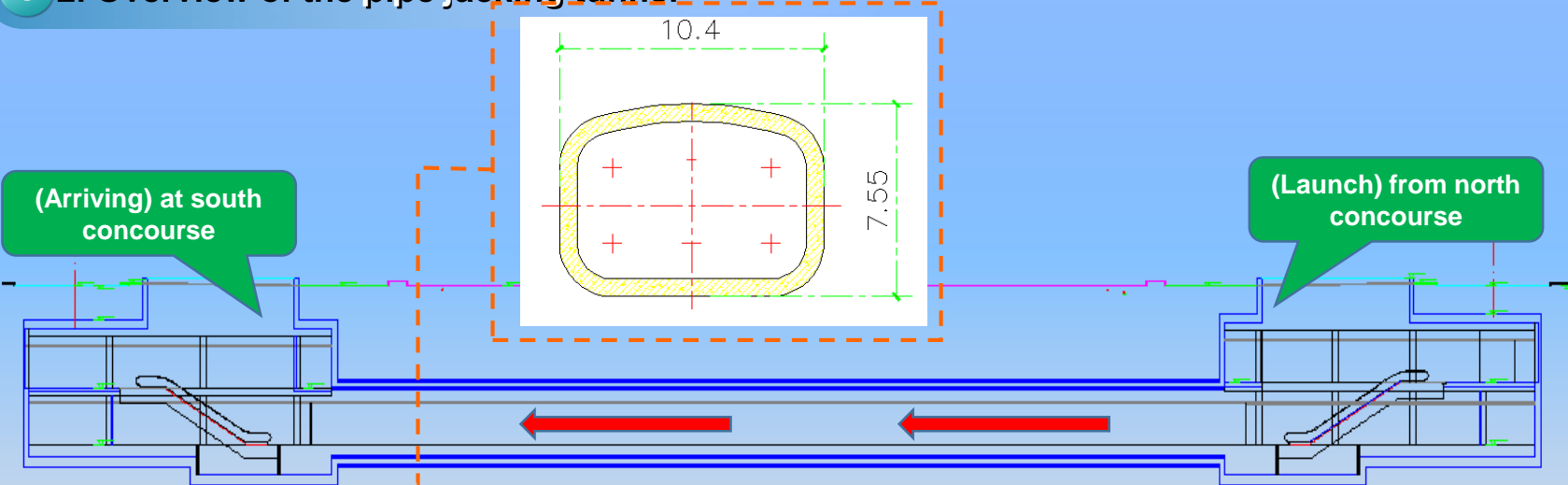
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→ 1. Project overview



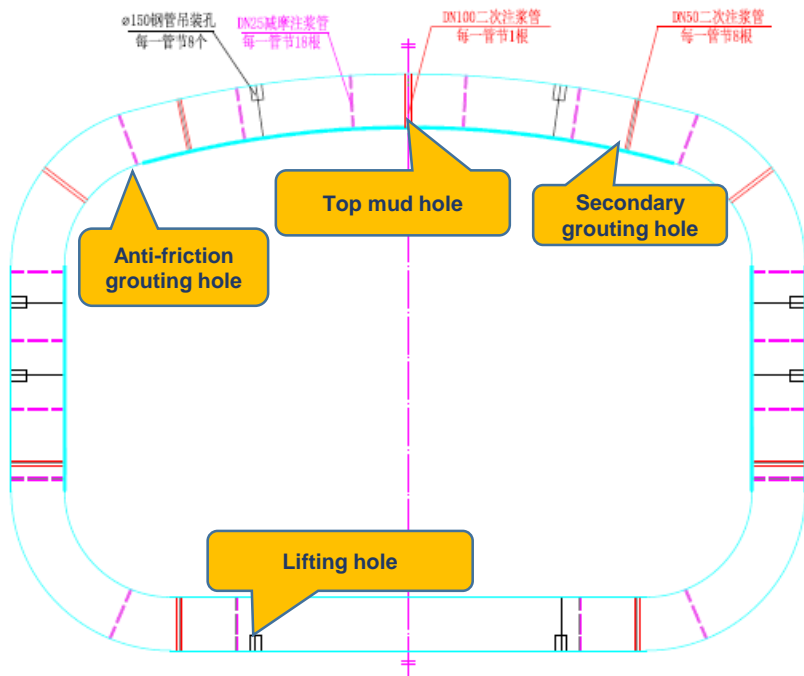
The rectangular pipe-jacking tunnel under Heiniucheng Road in Tianjin is located at the intersection of Heiniucheng Road and Neijiang Road in the New Badali area in Tianjin. The pipe jacking tunnel connects the north and south sides of the Heiniucheng Road. It is an underground pedestrian passage, and also serves as a comprehensive pipe gallery for the city's underground pipelines to pass through the Heiniucheng Road -- a trunk road in the city.

→ 2. Overview of the pipe jacking tunnel



The underground walkway beneath Heiniucheng Road is 92.6m long, and the cover soil is 8.17m thick. The tunnel was constructed through a pipe jacking method. The pipe sections are made of C50P12 reinforced concrete. The size of the cross-section of the tunnel structure is 10.42m by 7.55m, making it the largest section in the world. The pipe sections are 1.5m wide and 700mm thick. The number of pipe sections is 62, and the weight of a single pipe section is 77.2t. Socket-type F-shaped connectors are used for longitudinal connection between the rectangular pipe sections.

→ 3. Overview of pipe design



Embedded parts	Type A pipe section	Type B pipe section	Remarks
DN25 anti-friction grouting hole	18	17	Check valve on the outside
DN50 secondary grouting hole	8	8	5cm protective layer on the outside
DN100 secondary grouting hole	1	0	5cm protective layer on the outside
Φ 150 lifting hole	8	8	
Sliding chute	3	3	

The type-A pipe sections and type-B pipe sections are alternately arranged against the grouting holes and anti-friction grouting holes on the bottom plate. During the pipe jacking process, the type-A pipe section was set as the first pipe section, and the type-A pipe sections and type-B pipe sections are alternately arranged.

→ 4. Pipe section seam waterproof design

1) Outer waterproof system:

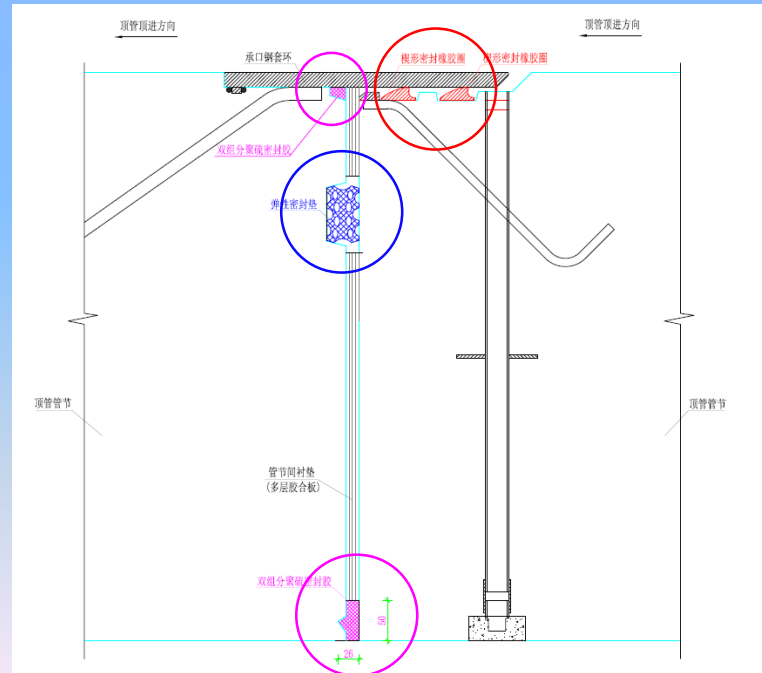
The female end of the pipe section has a steel sleeve, which is made of steel plate with a thickness of 18mm, and has a length of 350mm. The outer side of the male end of the pipe section is closely attached with two wedge-shaped rubber rings. During the construction, the male end is inserted into the steel sleeve. During the insertion process, the rubber ring is compressed to be closely attached to the steel sleeve, thereby forming a good waterproof system.

2) The second waterproof system:

Grooves are provided at the upper part of the pipe wall at the female end of the pipe section, and porous ethylene propylene diene monomer (EPDM) rubber gaskets are inserted into the grooves. The rubber gasket should have the same compression capacity as the multi-layer plywood to ensure the waterproof effect after assembly.

3) Inner waterproof system:

Caulking grooves are provided at the junction of two pipe sections on the inner side of the pipe sections, and a two-component polysulfide sealant can be injected later.





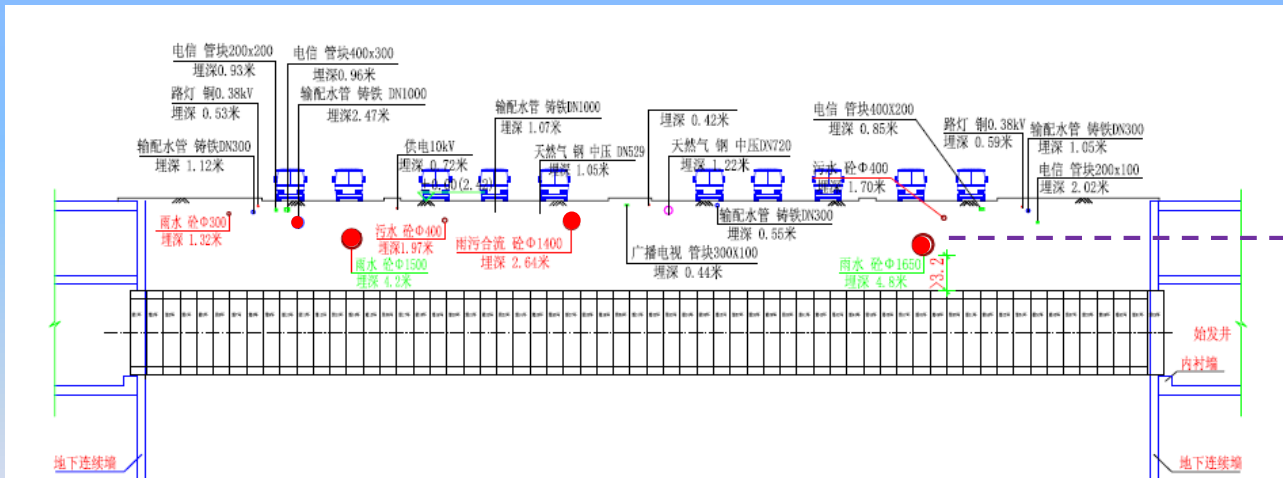
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Part II Project introduction



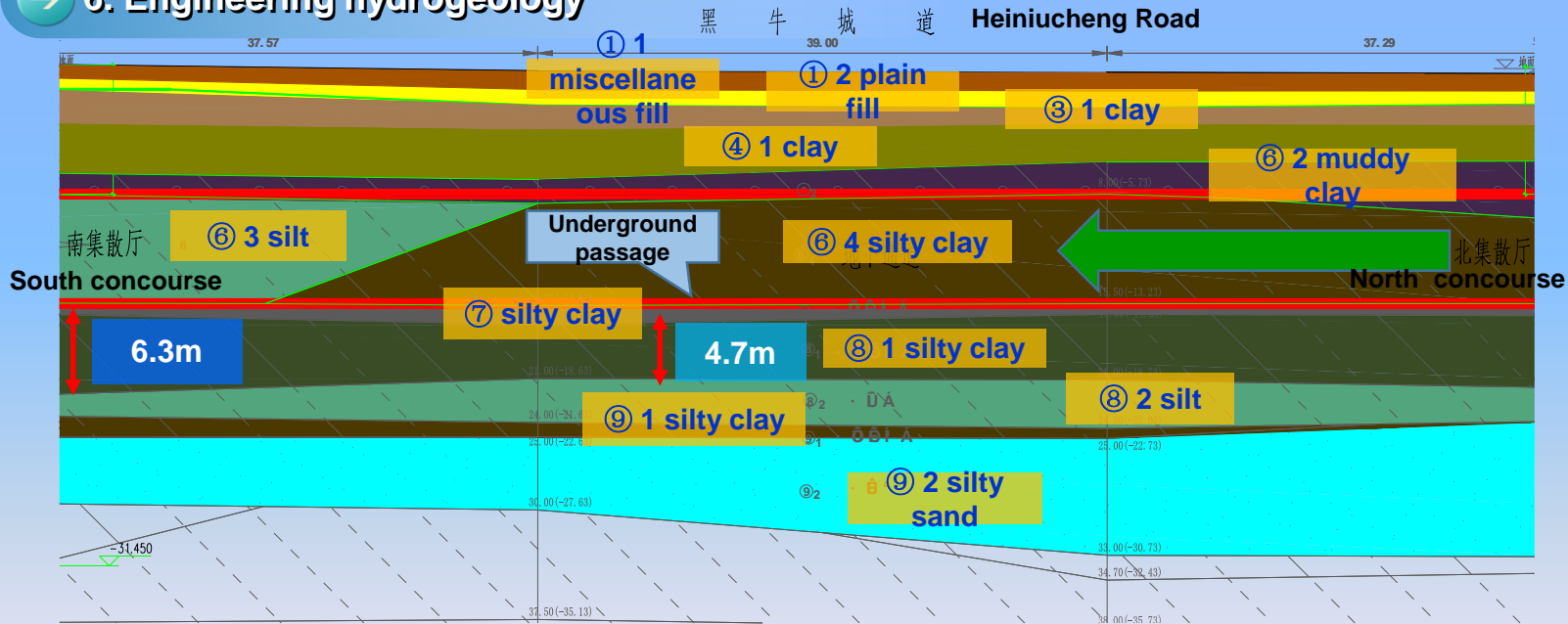
→ 5. The surrounding environment

There are no buildings around the underground passage beneath Heiniucheng Road. Around the area are mainly the main road, auxiliary roads and sidewalks of the Heiniucheng Road, and the green belts on both sides of the road. Heiniucheng Road is a trunk road in Tianjin with a width of 66.5m. The 10-lane, two-way street is very busy with heavy traffic.



The pipe-jacking tunnel runs below the Heiniucheng Road with a total of 22 pipelines above. The closest pressure pipe is a DN1000mm water supply pipe (6m from the pipe jacking tunnel), while the closest non-pressure pipe is a Φ1650 rain water pipe (3.6m from the tunnel), which is located on the north auxiliary road of the expressway.

6. Engineering hydrogeology



The top-down distribution of soil of the underground passage is: ① 1 miscellaneous fill, ① 2 plain fill, ③ 1 clay, ④ 1 clay, ⑥ 2 muddy clay, ⑥ 3 silt, ⑥ 4 silty clay, ⑦ silty clay, ⑧ 1 silty clay, ⑧ 2 silt, ⑨ 1 silty clay, and ⑨ 2 silty sand.

The tunnel is mainly composed of ⑥ 3 silt and ⑥ 4 silty clay.



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Part III Key innovations

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Part III Key innovations



In this project, the pipe sections of the underground walkway has the largest cross section in the world - 10.4m*7.55m. In the meantime, it is the first time a super-large section rectangular pipe-jacking tunnel was built in the watery and weak strata in Tianjin. Therefore, there was no similar experience that can be used for reference. During the course of this project, we have overcome many technical problems during construction of the pipe jacking tunnel, such as dynamic waterproofing, attitude control of the pipe jacking machine and pipe sections, high-precision pipe section prefabrication extremely cold weather, and deformation control of the ground and pipelines.

Measures for preventing seepage and leakage of water in the water-rich and weak stratum during the pipe jacking construction, especially the risk control measures for preventing gushing muddy water during launch and arrival

Attitude control and corrective measures for pipe jacking machine during construction

**Key
innovations**

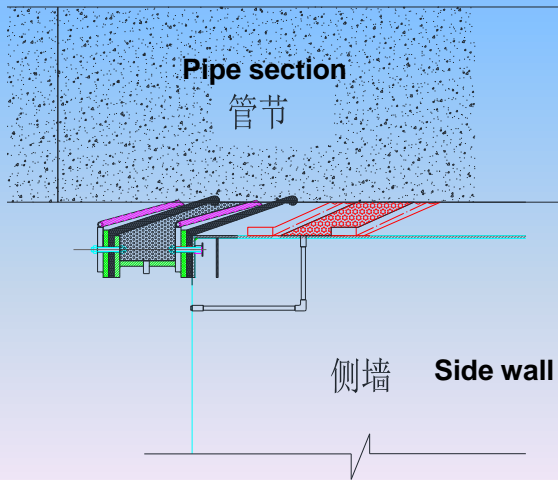
Measures for guaranteeing prefabrication quality of super-large section pipe sections and for ensuring the precision of embedded parts in extremely cold weather

Measures for controlling settlement of ground surface and pipelines during the construction process to ensure the safety of the surrounding environment and safe driving on the road

→ 1. Technical measures for preventing seepage and leakage during pipe jacking construction

Inject grease into wire brushes at tunnel doors to prevent seepage and leakage

As for waterproofing at the tunnel door rings, with reference to the principle of shield tail brush in the shield method, two layers of wire brushes are provided on the inner side of the embedded steel rings on the side wall at the tunnel door, and grease is continuously injected into the wire brushes through pre-buried pipes to ensure dynamic waterproofing of the tunnel door.



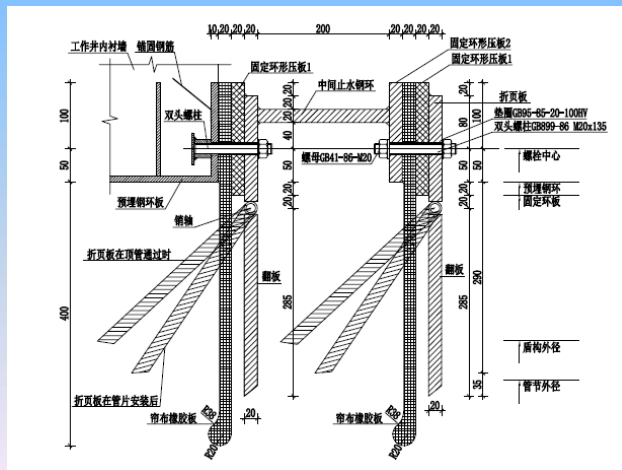
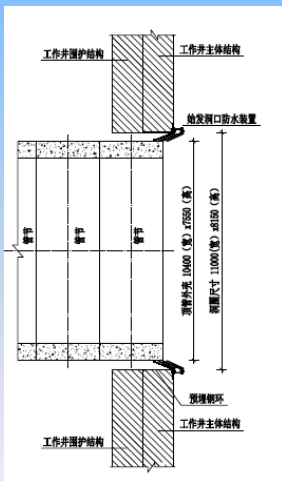


Part III Key innovations



Inject inert slurry into the extension steel box at the tunnel door to prevent seepage and leakage

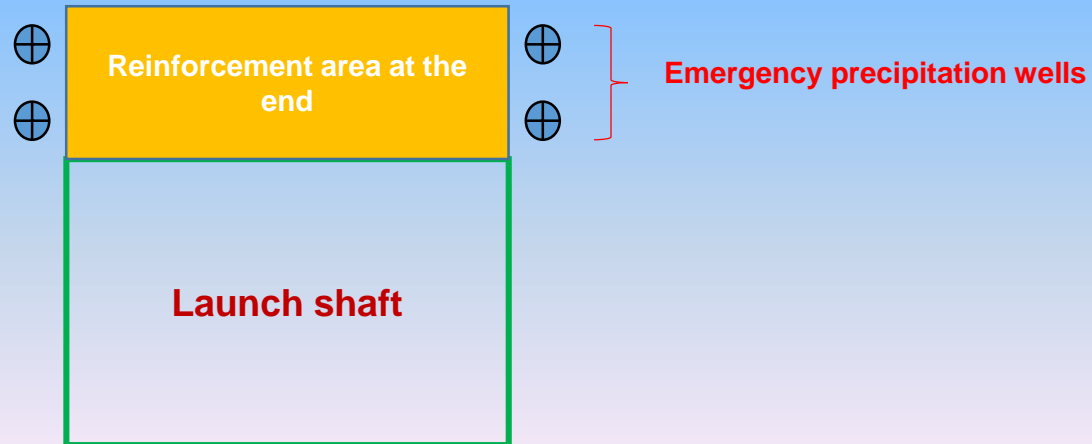
In order to prevent the soil and groundwater from flowing out from the gap between the jacking pipe casing and the door during launch and propulsion, the door sealing is made of two layers of flap-type sealing plates + two layers of cord rubber plates. A grouting ball valves was pre-embedded in the steel box. During the launching and construction process, inert slurry was injected into the steel box of the tunnel door for dynamic waterproofing and sealing.



→ 1. Technical measures for preventing seepage and leakage during pipe-jacking launching

Measure 3: Dig emergency precipitation wells to prevent seepage and leakage

There are 4 precipitation wells at the end of the launching shaft. The precipitation wells start from the ground, and the depth of the wells is 1.5m below the bottom of the reinforcement. This is to lower the groundwater level and ensure the safety of the launch. Before the launch, a test was carried out in which the water was pumped out from the alternate precipitation wells, so as to ensure that the precipitation wells can effectively lower the water level and operate normally. When a dangerous situation occurs, water will be pumped out to reduce pressure according to the severity of the danger.



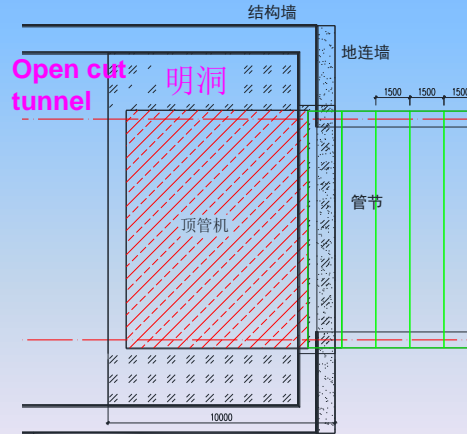
Part III Key innovations

→ 1. Technical measures for preventing seepage and leakage in pipe jacking construction

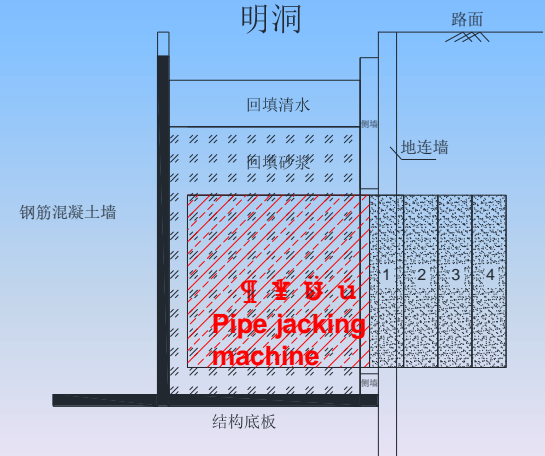
In order to ensure the safety of arrival when using the pipe jacking machine, open cut tunnel construction was adopted during the arrival process, and the open cut tunnel has a reinforced concrete frame structure. After the diaphragm wall is broken, the backfilling operation was immediately carried out on the open cut tunnel. Low-grade mortar was backfilled into the space from the bottom of the bottom plate to 3m above the top of the jacking pipe, and the mortar strength was not more than 1MPa after 28d.



Mortar backfill



Plan view of open cut tunnel arrival



Sectional view of open cut tunnel arrival



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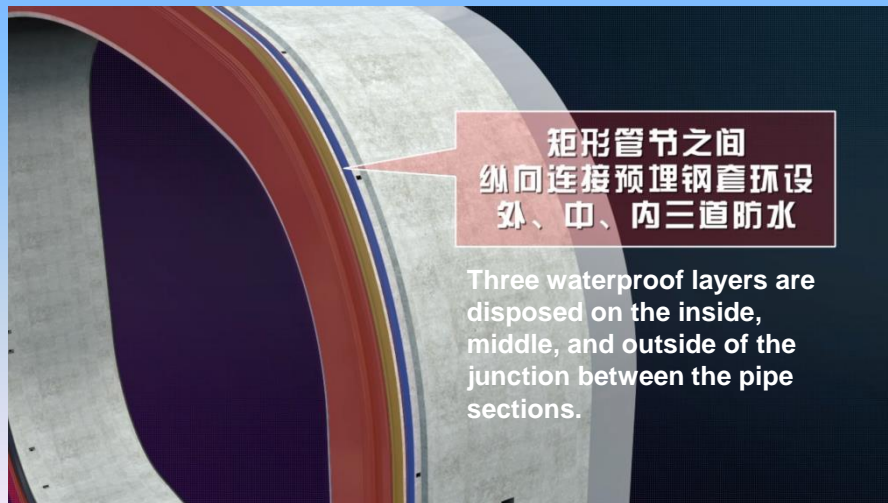
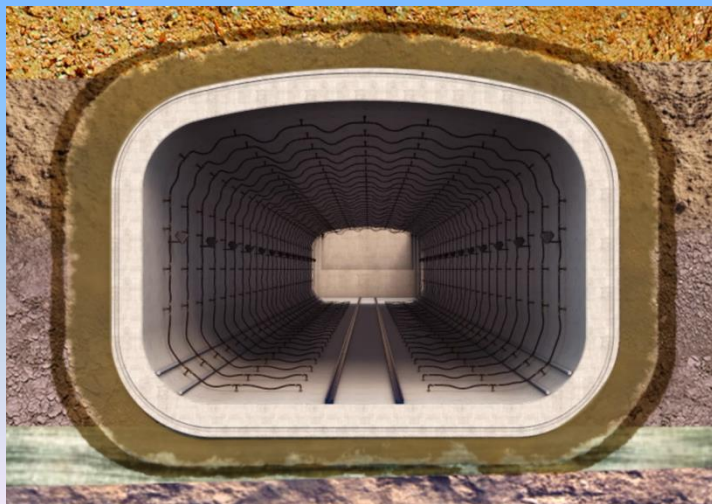
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Part III Key innovations



→ 1. Technical measures for preventing seepage and leakage in pipe jacking construction

During the pipe jacking process, a large amount of thixotropic mud was injected, and three waterproof layers are disposed on the inside, middle, and outside of the junction between the pipe sections.



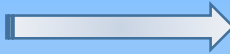
→ 1. Technical measures for preventing seepage and leakage in pipe jacking construction

Main points of waterproofing
technology in pipe jacking

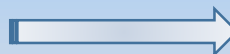
Pipe section seam
water proofing



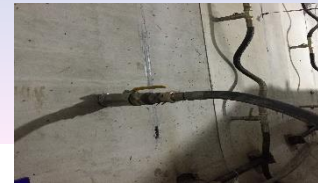
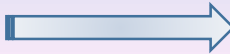
Pipe section seam
fastening



Pipe section caulking

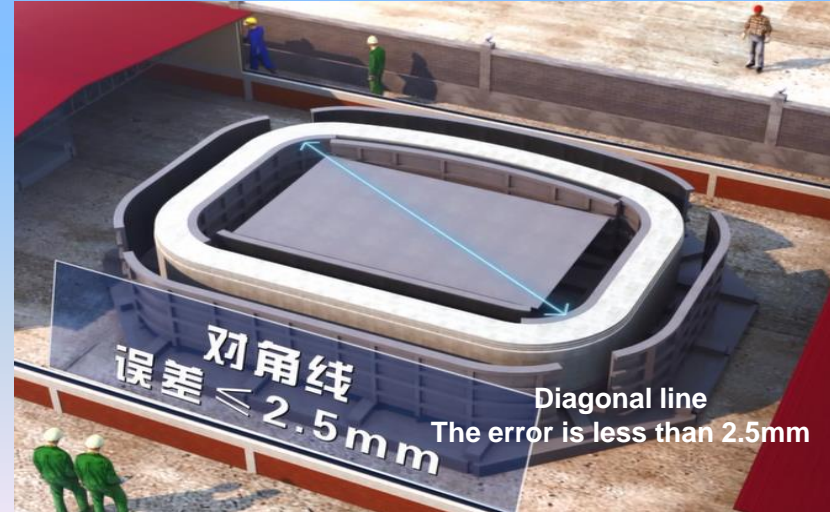
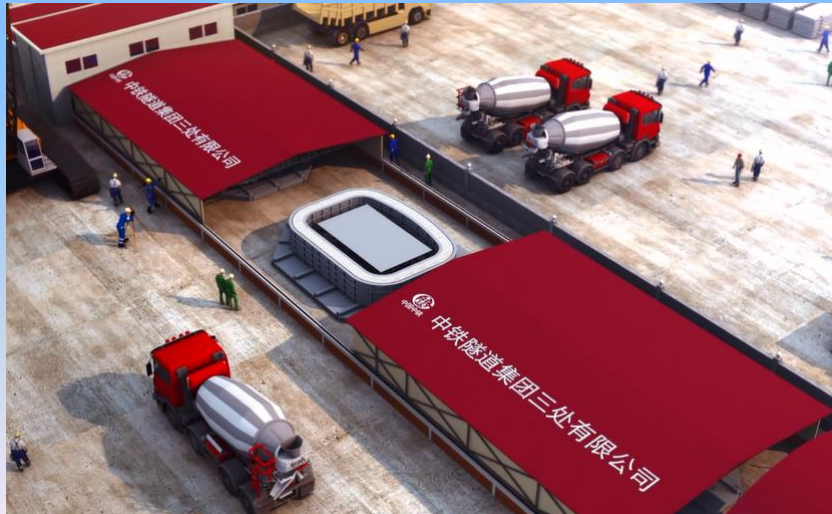


Tunnel consolidation



→ 2. Technical measures for pipe section prefabrication

In order to ensure the prefabrication quality of the pipe sections, a standardized pipe section fabrication plant was established on site. High-precision steel formwork and steam curing equipment were used to ensure the prefabrication accuracy and prefabrication speed of the pipe sections. A hydraulic system was used for clamping, and the inner and outer molds are tightened by large screws and bolts. The molds are bolted into whole pipe sections. The deviation of the F-type socket joints was controlled within plus or minus 2mm.



→ 2. Pipe section prefabrication -- concrete curing

As the construction took place in winter, the pipe sections were steam-cured. The temperature was measured automatically. Once the strength of the pipe sections meet the requirement of lifting strength, the pipe sections were covered with tarpaulin for heat preservation and maintenance after lifting.



**Steam
generator**



**Pipe section
steam curing**

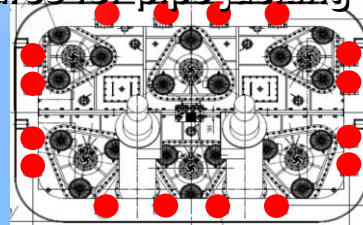


**Insulation
maintenance**

→ 4. Attitude control and corrective measures for pipe jacking machine



**Improvement and
excavation of muck**



**Articulated
cylinder**

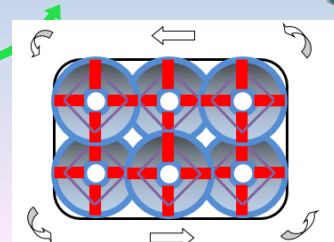


**Auxiliary
mud filling**

**Launch
positioning**

**Guidance
system**

**Cutter
rotation**



→ 5. Ground subsidence and pipeline deformation control

Selection of pipe jacking equipment

During the jacking construction, pipe jacking machines that ensure that there's no gap between the cutter heads and the casing were selected for use. At the same time, the size of the pipe jacking machine is 10mm larger than the size of the pipe sections of the tunnel, which is very favorable for controlling the settlement of the ground surface and pipelines. During the pipe jacking process, thixotropic mud was injected for lubrication and supporting the formation.



There's no gap between the cutter heads and the casing of the pipe jacking machine.

During the pipe jacking process, the injection of thixotropic mud has the effect of lubrication and supporting the formation.

Part III Key innovations

→ 5. Ground subsidence and pipeline deformation control

Ground subsidence and pipeline deformation control

Soil bin pressure

Thixotropic mud

Stoppage device

Unearthed amount

Void filling





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Part IV Project evaluation

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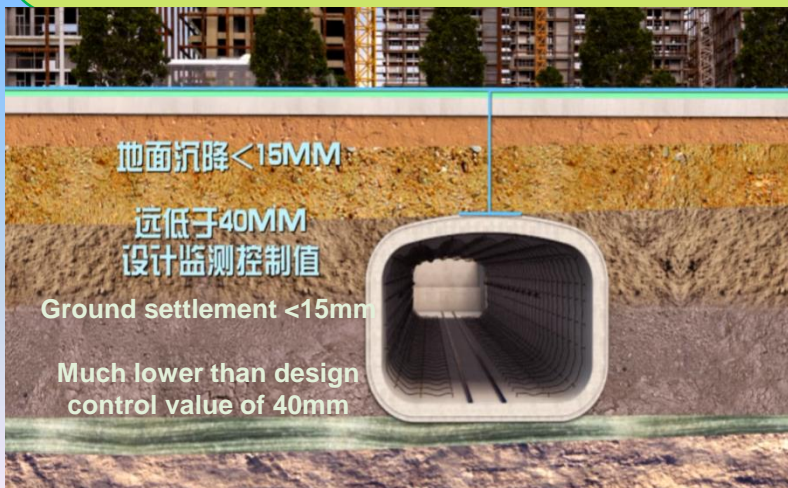
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Construction effect:

1. Through careful organization and scientific construction, the pipe jacking was completed in only 62 days, ensuring an average daily construction speed of 1.5m/day.
2. During the construction process, the impact on the surrounding structures was controlled within 15mm.
3. No water inrush occurred in both the launching and arriving of the tunnel.
4. The axis deviation was controlled within 10mm.
5. There is no seepage or leakage in the joints of the pipe sections, and the overall tunnel is in good condition.

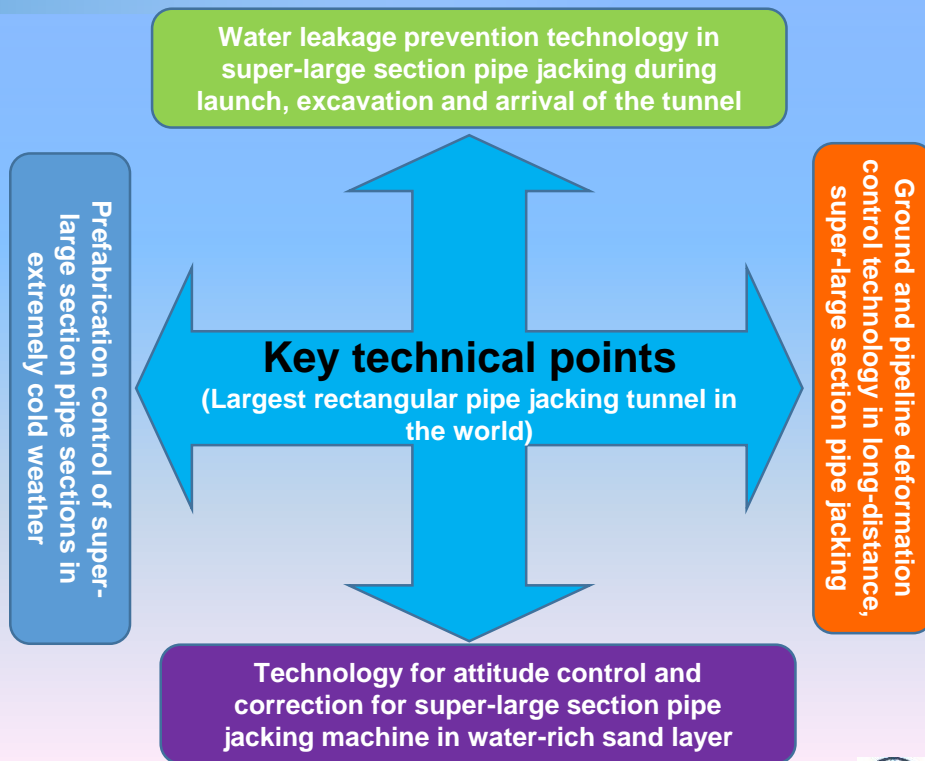


→ 2. Inspection of the effect after completion of the pipe jacking tunnel

During the construction of this project, we have overcome the technical difficulties of high-precision pipe section prefabrication, dynamic waterproofing in launching and arriving, ground and pipeline deformation control, and attitude control of the pipe jacking machine and pipe sections. Before and after the construction, deformation of the ground and pipelines meets design and specification requirements. After consolidation, there's no seepage in the structure inside the tunnel.



→ 3. Summary of key technologies



Honors

Obtained 1 provincial-level construction method in Henan Province and 1 municipal-level construction method in Tianjin.

Obtained 2 utility model patents and 3 invention patents.

Published 3 papers in core journals.

Thanks for your time!

