



上海隧道工程股份有限公司
SHANGHAI TUNNEL ENGINEERING CO.,LTD.



同濟大學
TONGJI UNIVERSITY

AGS (HK) & HKIE Geotechnical Division Joint Evening Talk

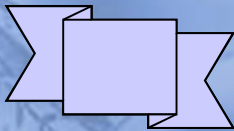
Artificial Ground Freezing

Hu Xiangdong

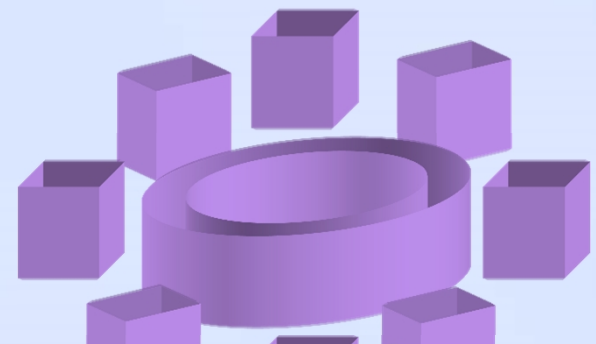
2013-10-28

TOPICS

Introduction to Artificial Ground Freezing
Application of AGF in Tunneling Works
Risk and Control Measures
Case Study



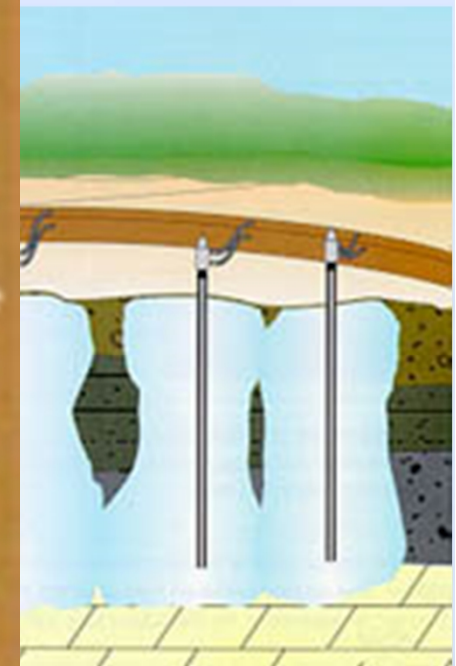
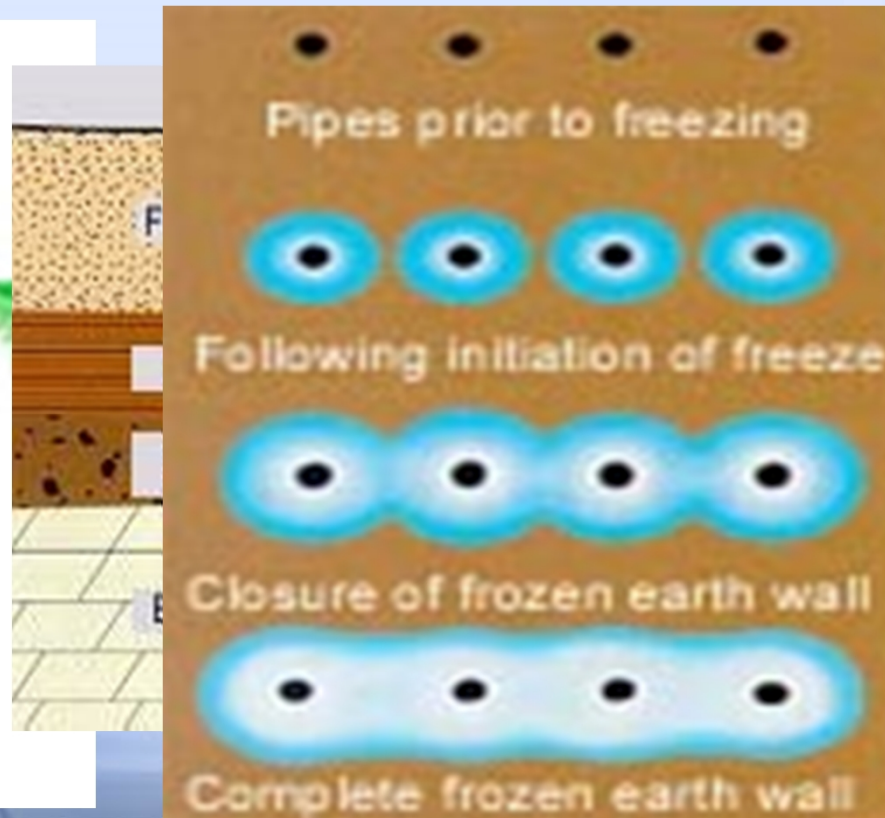
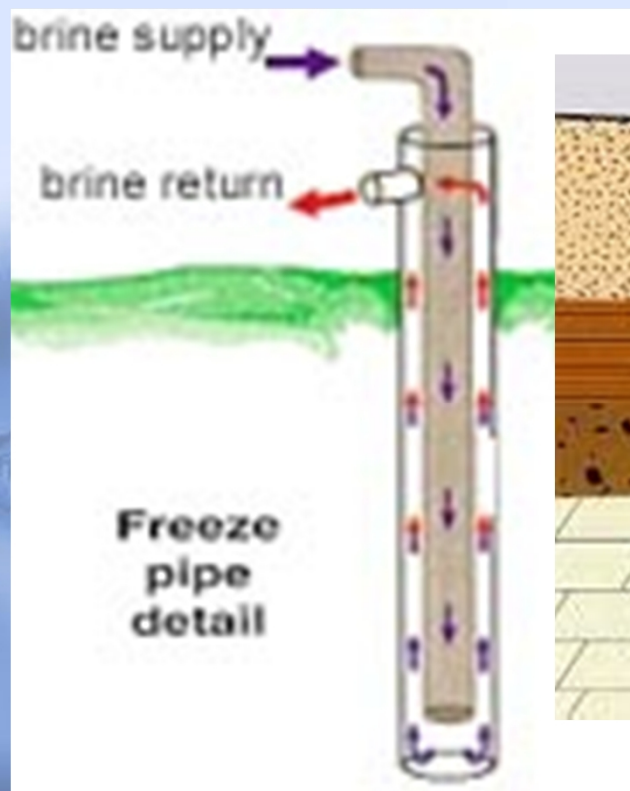
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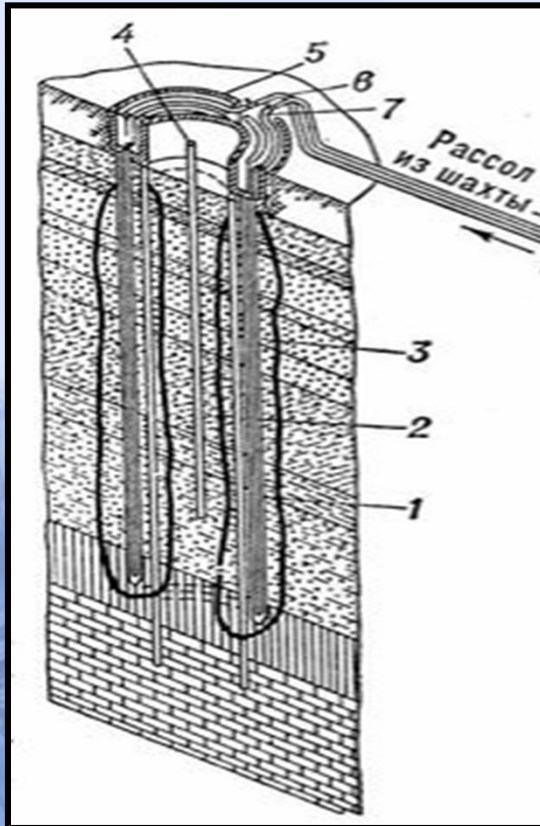
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Principle of Artificial Ground Freezing

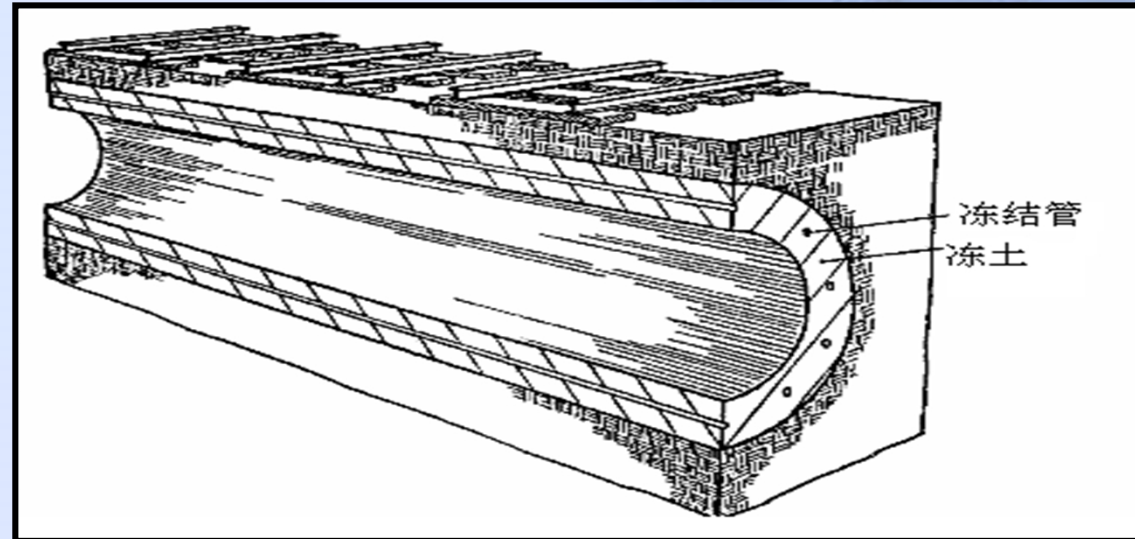
Artificial Ground Freezing (AGF) is a special construction technology through which artificial freezing is used to temporary change rock/soil properties at certain soil strata by **consolidation**.



Principle of Artificial Ground Freezing



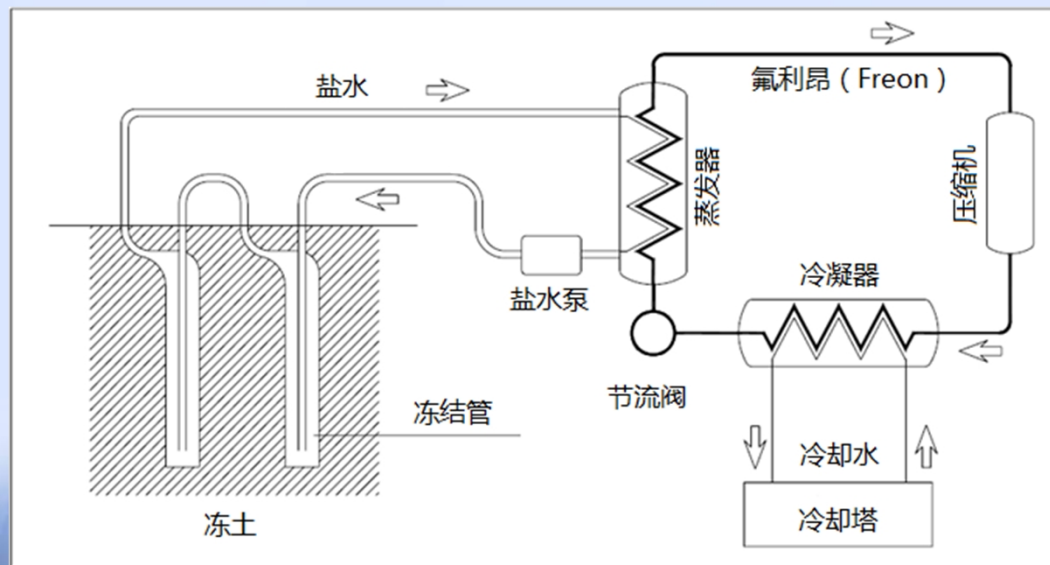
vertical freezing



Horizontal freezing

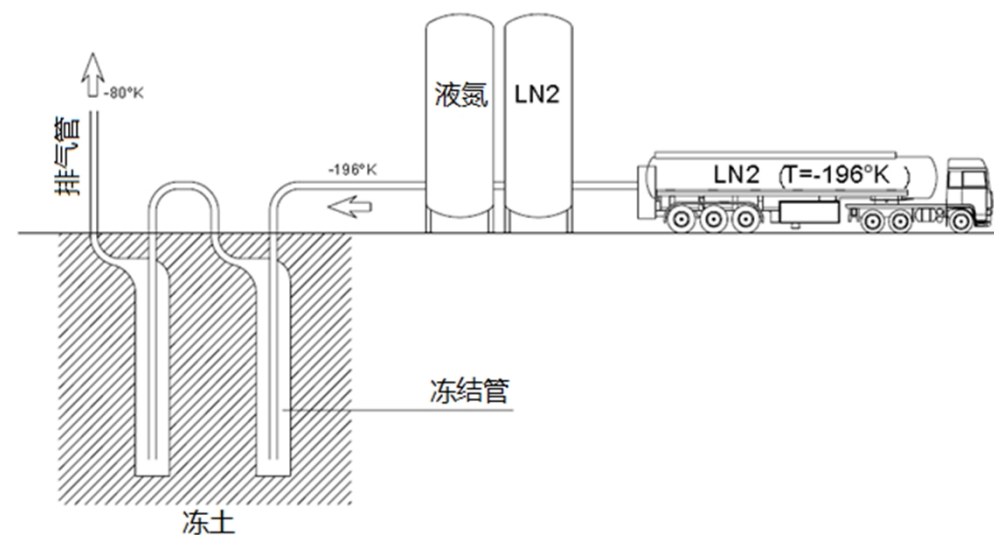
According to freezing pipe arrangement, there are **vertical freezing** and **horizontal freezing**.

Principle of Artificial Ground Freezing



**Brine freezing
-Indirect freezing**

**Liquid Nitrogen (LN) freezing
-Direct freezing**



Principle of Artificial Ground Freezing

Comparison of refrigeration methods

	LN Freezing	Brine Freezing
Freezing Plant	Simple, no equipment	Complex, big equipments
Electrical Power	No	Large cost
Min. Temp.	-196°C	-30°C
Frozen soil	Low temp., high strength	High temp., low strength
Freezing rate	Rapid	Slow
Environmental impact	No pollution, no noise, no vibration	Noise, occasional brine leakage
Cost-effective	Not good	Good
Applicability	Economic for small volumes or time critical operations	Economic for large volumes and/or long time periods
Controlability	Not easy	Easy
Risk	Cold burns and lack of oxygen	

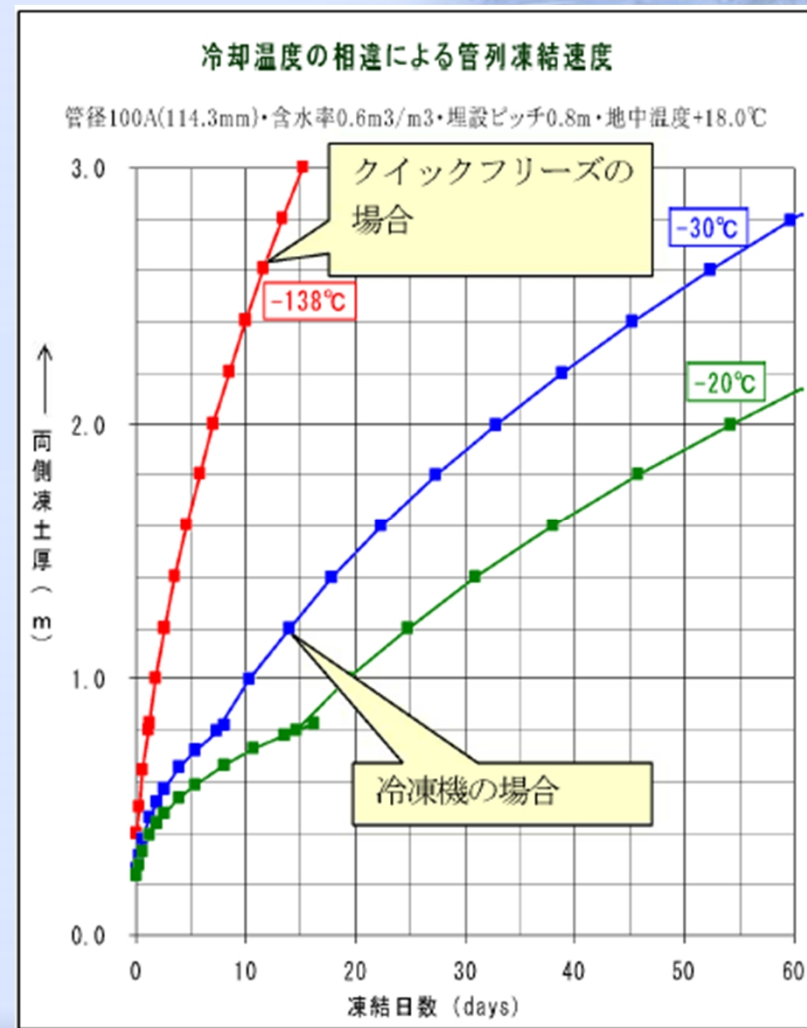
Principle of Artificial Ground Freezing



Comparison of refrigeration methods

Freezing rate:

1week by LN
= 1 month by brine



After SEIKEN Co. Ltd.

Frozen soil structure characteristics



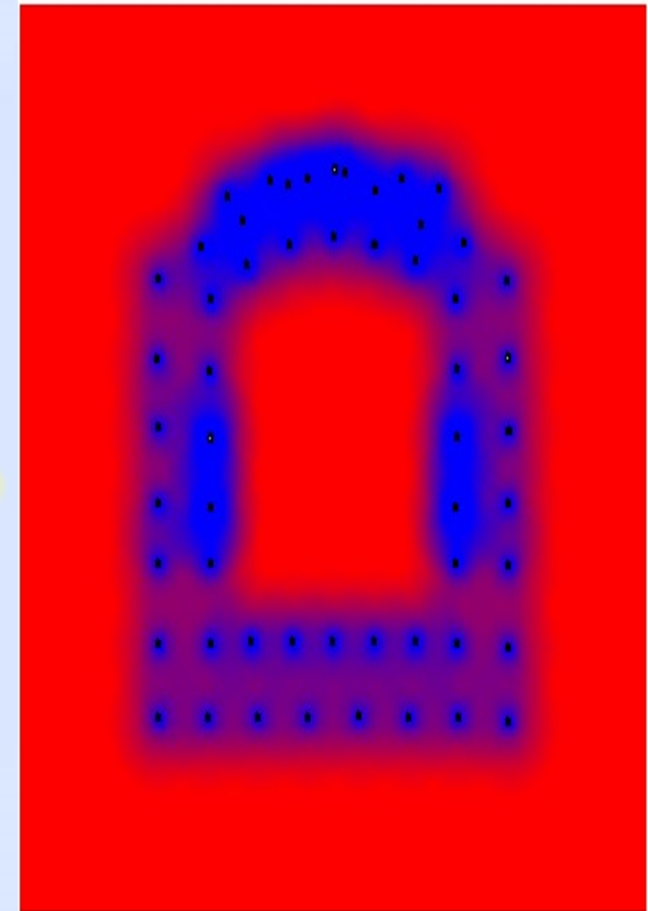
Good water tightness

High soil strength

Low risk on loss of ground & strength

Soil strength could be monitored
by temperature

Soil strength could be
controlled by temperature

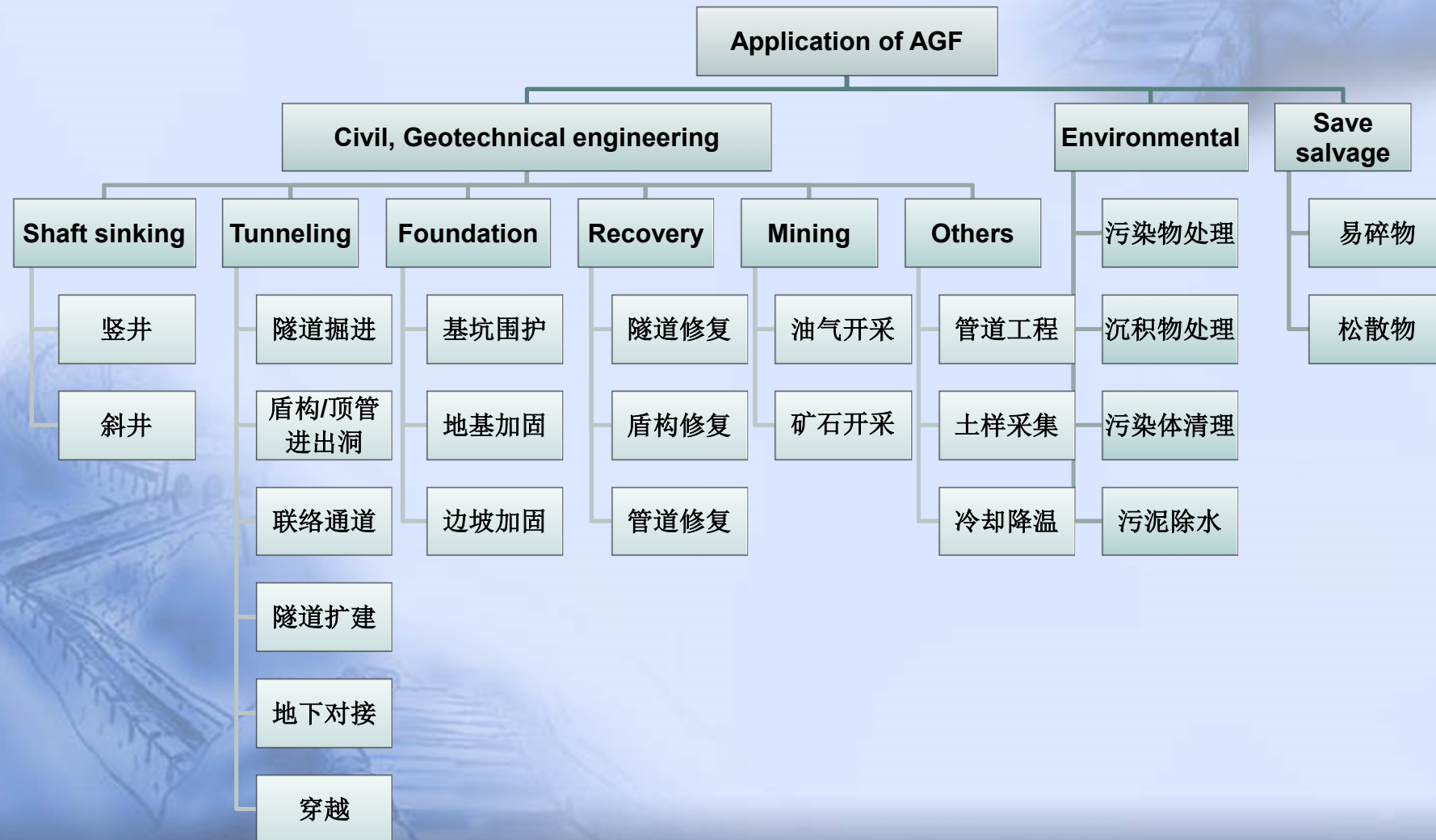


History of Artificial Ground Freezing



- ◆ **In 1883**, freezing method was initially used to sink a shaft for a coalmine in Kaebari, German, with success.
- ◆ **In 1955**, freezing method was initially used to excavate shaft for coal mine in **China**.
- ◆ By the end of **1960s**, freezing method was initially used in **Beijing** metropolitan.
- ◆ Currently, freezing method is widely used in cross passage and shield break-in and break-out reinforcement construction for metro tunnel in most of the metro cities, such as Shanghai, Beijing, Tianjin, Guangzhou, Shenzhen...

Application of Artificial Ground Freezing



Application of AGF in Tunneling Works



- **Cross-passage construction**
- **Ground reinforcement for shield launching or arriving**
- **Tunnel restoration**

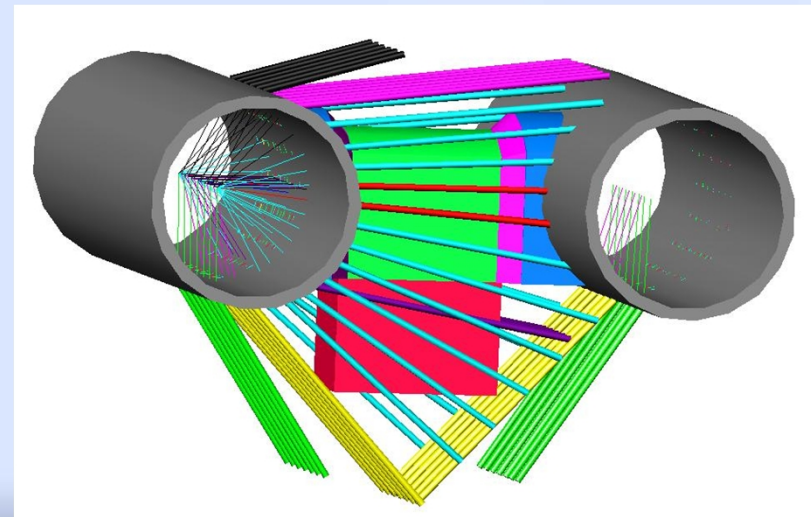
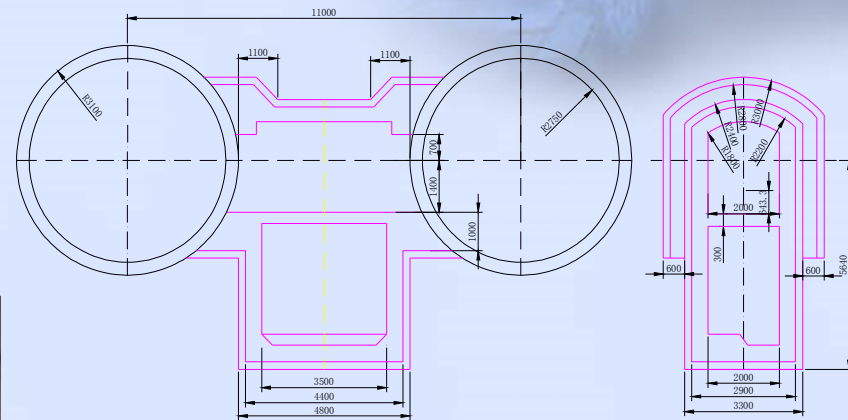
Application of AGF in Tunneling Works



1

Cross-passage construction

Cross-Passages in Metro (with drainage sump)



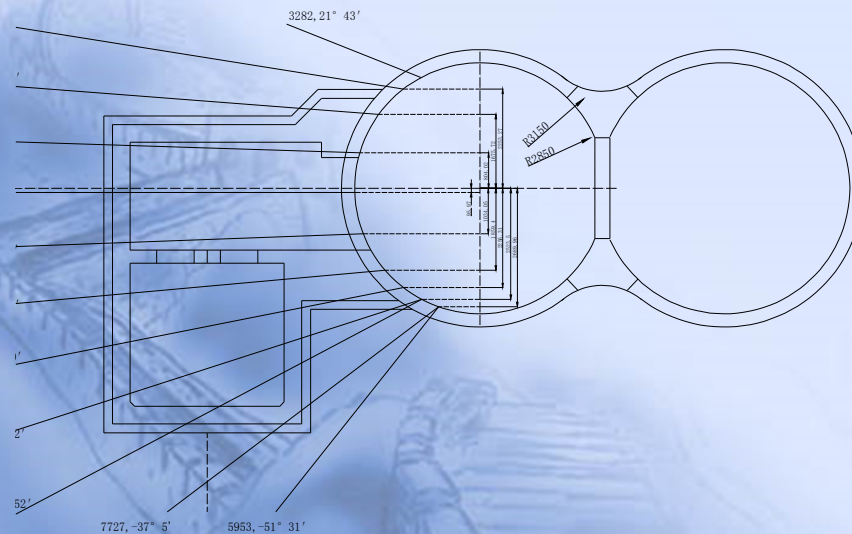
Application of AGF in Tunneling Works



1

Cross-passage construction

Drainage Sump in Metro (in DOT)

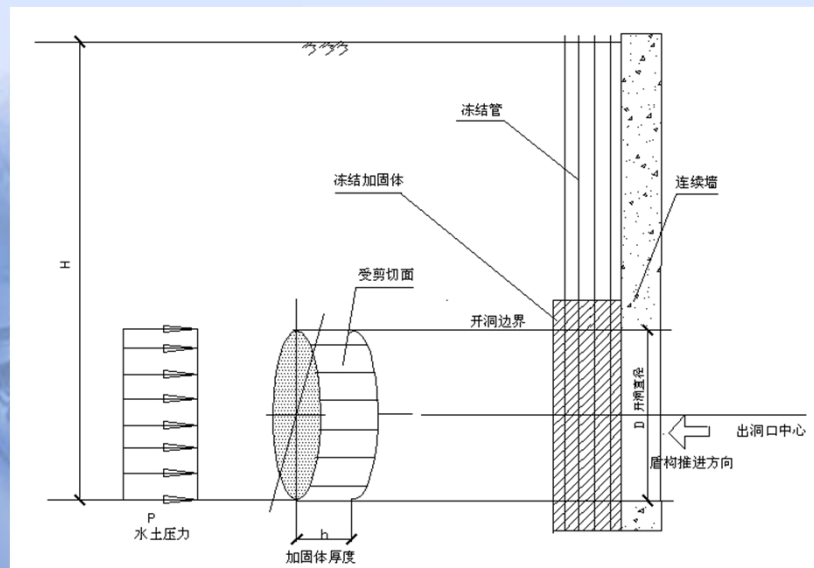


Application of AGF in Tunneling Works



2

Ground reinforcement for shield launching or arriving



Application of AGF in Tunneling Works



2

Ground reinforcement for shield launching or arriving

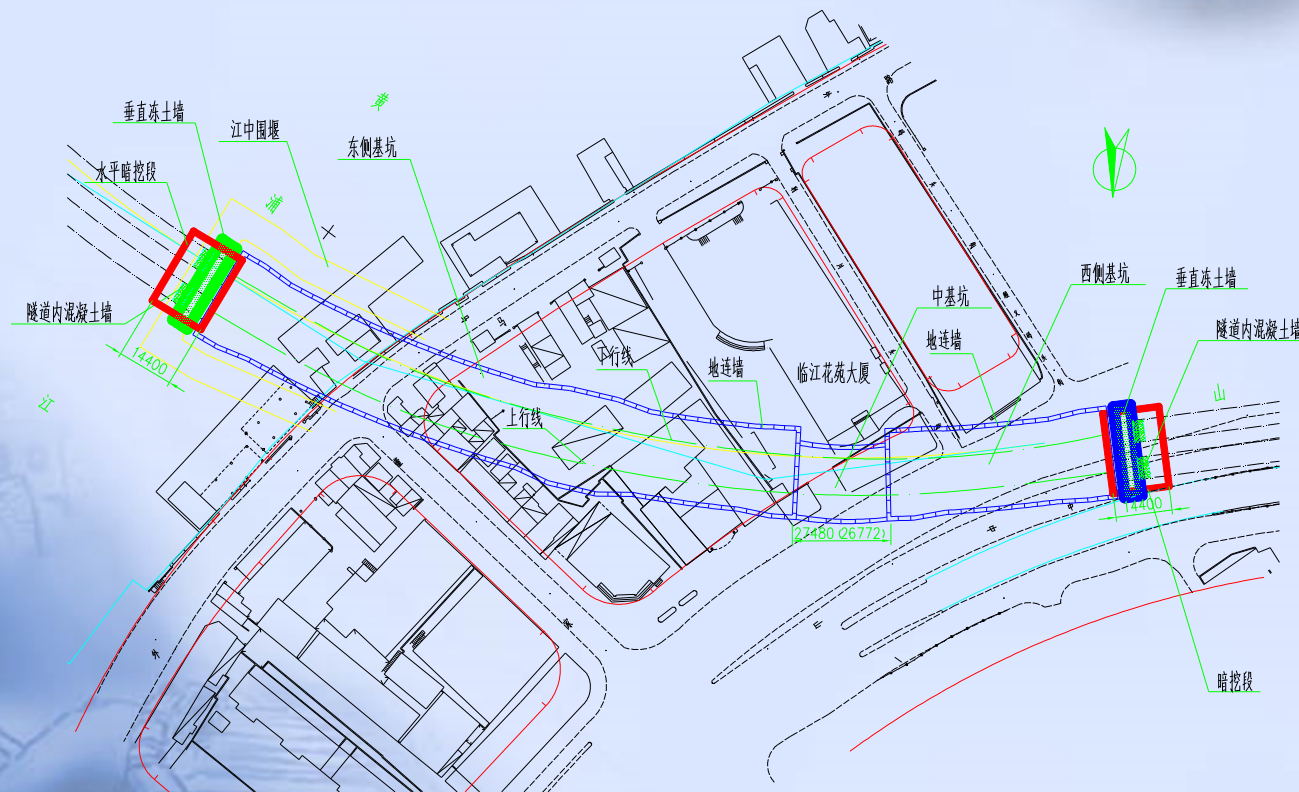


Application of AGF in Tunneling Works



3

Tunnel restoration



Restoration of the tunnel collapse of Line 4, Shanghai Metro

Measures for risk control



Three Critical Risks:

- Drilling from within sub-surface space
 - **Water and soil ingress**
- Freezing and excavation
 - **Segment deformation**
- Ice-wall failure
 - **Flood and tunnel collapse**

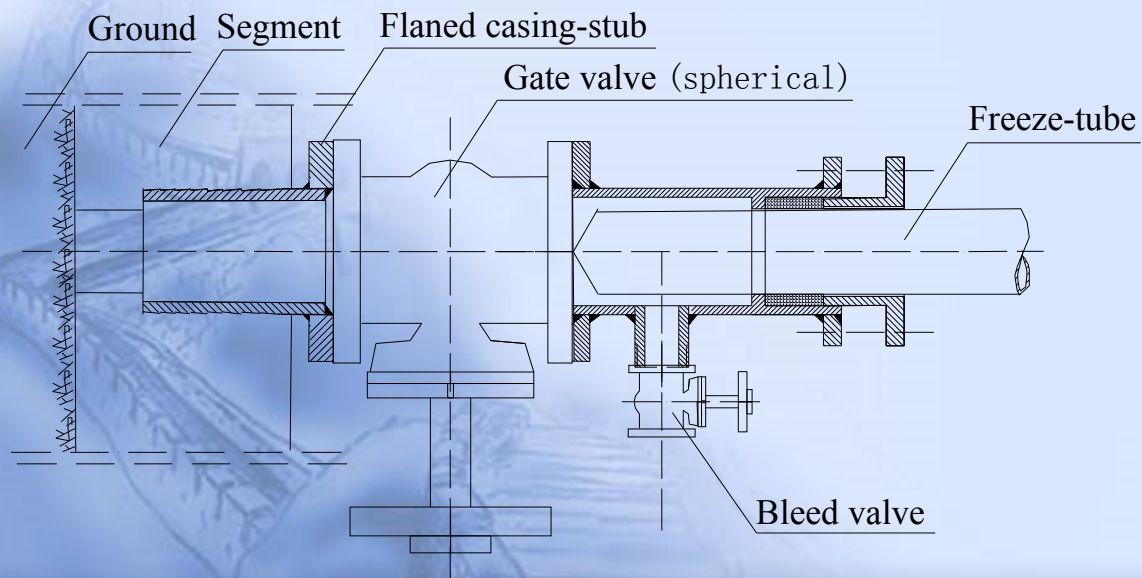
Measures for risk control



1

Drilling from within tunnel

Using stuffing-box
- As Blow-Out Preventer (BOP)



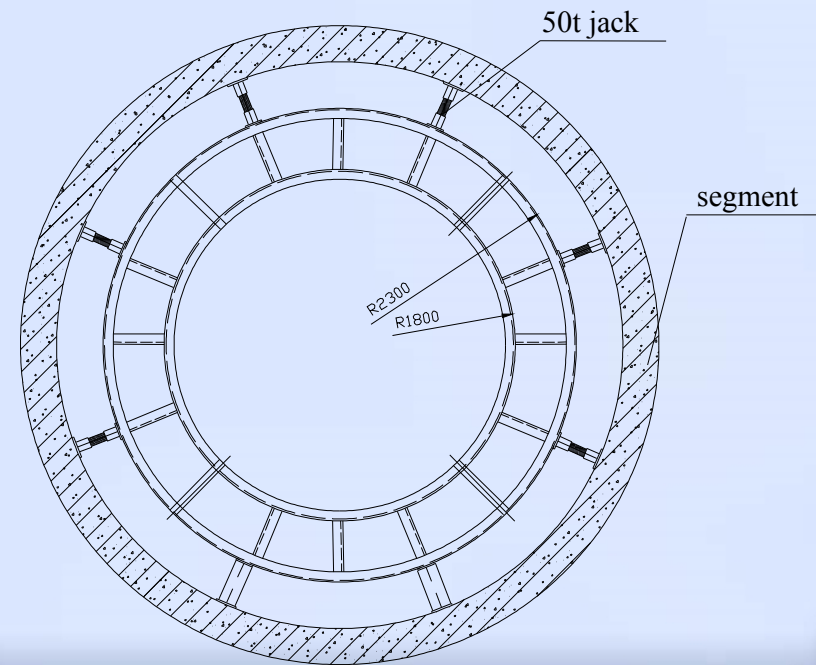
Measures for risk control



2

Tunnel deformation limitation

Prestressed deformation limitation support

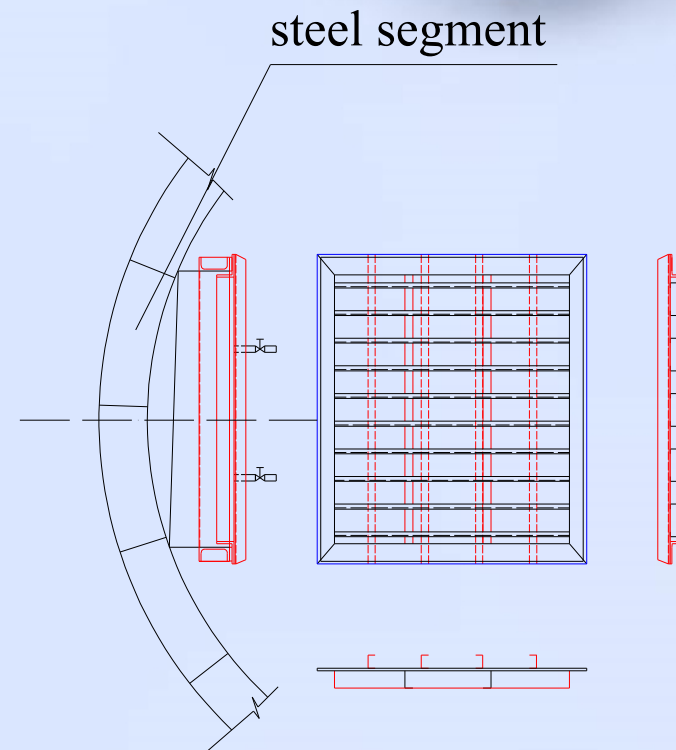


Measures for risk control



3

Flood-prevention facility



Safety door

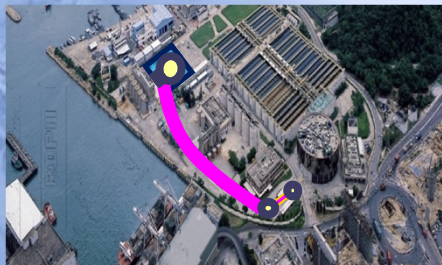
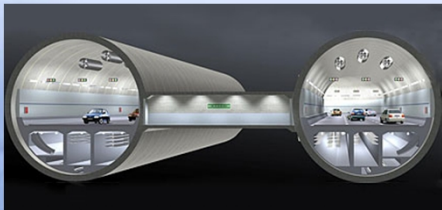
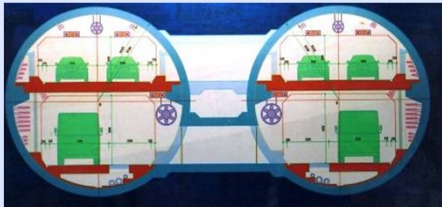
Experience of STEC



Experience of STEC

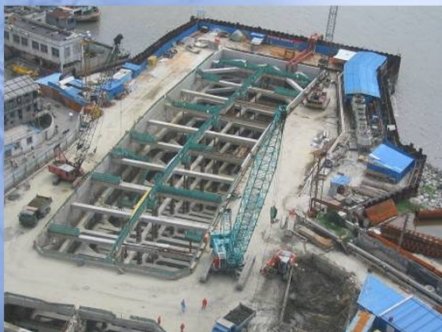
No.	Project name	Length	Overburden	Project type/parts/location	Remarks
1	Shanghai Yangtze River tunnel project(shield with largest diameter in the world)	15	33~39	8 cross passages circular section with diameter around 5m	cases - tunnel excavation by NATM
2	Metro No.9, Shanghai	12	21.6	cross passage	
3	Xinjian road tunnel	25	35	road/cross passage	
4	Tianjin metro	13	17	cross passage	
5	Hangzhou metro	12	23.5	cross passage	
6	Shantou Huaneng electricity factory project	—	25	reinforcement	cases – shield break-in and break-out soil improvement
7	Nanjing metro	—	15	shield break-in	
8			16	shield break-out	
9	Hangzhou metro	—	23	shield break-in	
10			23	shield break-out	
11	Shanghai Qingcaosha raw water supply project	—	18	shield break-in	
12		—	23	shield break-out	

Case Study



- **Cross Passage Construction of East Fuxing Rd. Double-Deck Cross-River Tunnel (Shanghai)**
- **Cross Passage Construction in the Shanghai Yangtze River Tunnel (Shanghai)**
- **Stonecutters Island Sewage Treatment Works (Hong Kong)**

Special Cases



- **Shantou Undersea Tunnel Repair**
- **Replacement of the wire brush tail seal during the long-distance shield driving in Shanghai Yangtze River Tunnel**
- **Restoration of the tunnel collapse of Line 4, Shanghai Metro**