The Application Progress of Fire Engineering in the Construction of Underwater Tunnel in China

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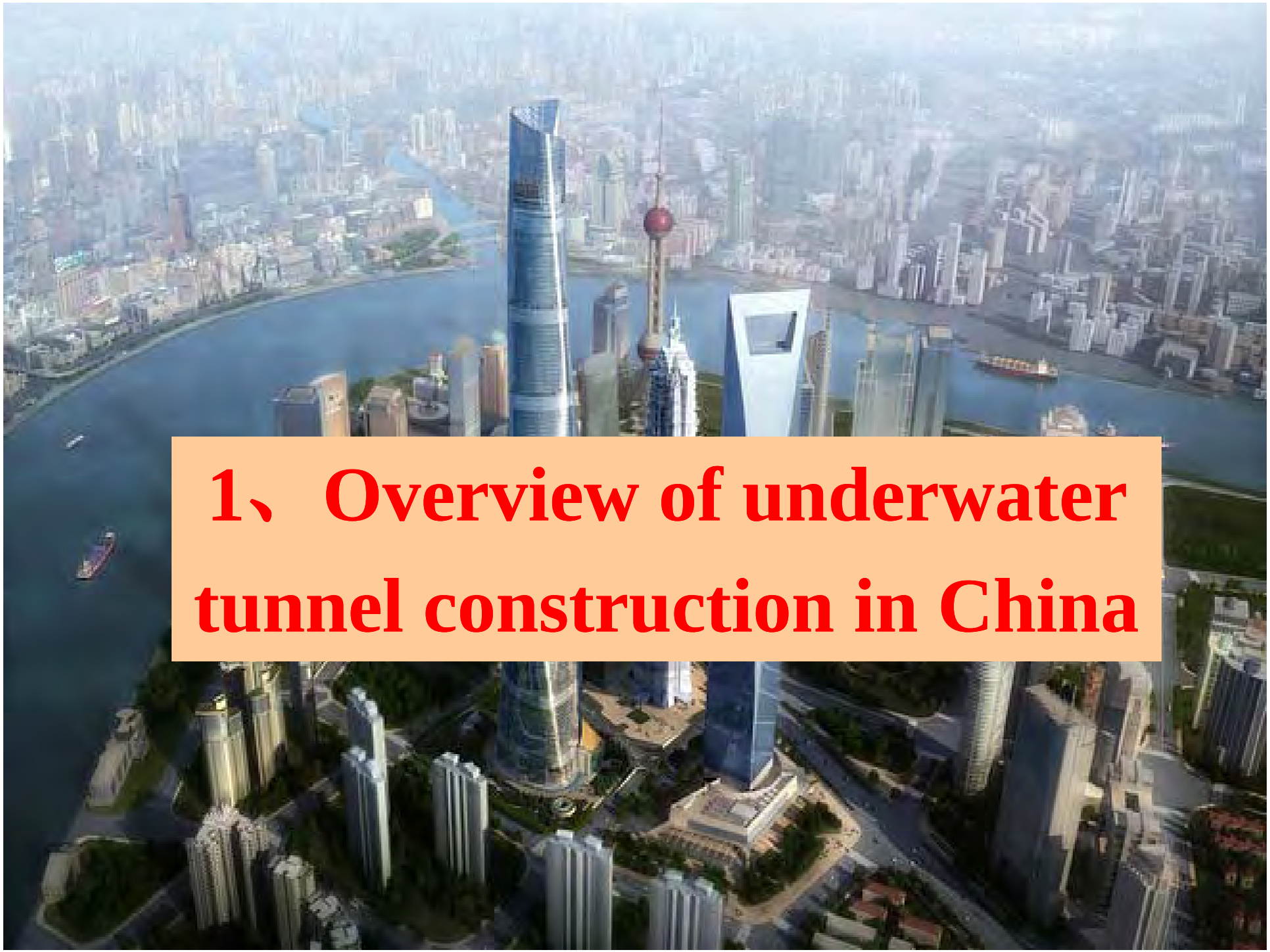

1、Overview of underwater tunnel construction in China

1 Overview of underwater tunnel construction in China

Where?

- To through mountain
- River, sea channel
- Urban district

Why?

- Regional economic development
- Environmental Protection
- saving land,

Expensive ?

- Technological progress
- Labor cost, distance shorter

1 The overview of tunnel construction in China

The tunnel construction in China by 2010

	Amount	Length(km)
Railway (In used)	8900	6000
Railway (Under building)	2500	4700
Highway	6139	4920
Railway >4km	190	821
Underwater	30	?

1 Overview of underwater tunnel construction in China

No.	Name	Length (m)	Lane	Time	Remark
1	Shanghai Huangpu	2736	2×2	1971	The first underwater Huangpu river
2	Xiamen xiangan	8695	2×3	2010	The first under sea
3	Wuhan Yangtze	3200	2×2	2008	The first under Yangtze river
4	Shanghai Yangtze	8950	2x2x1	2009	Under Yangtze river Double deck with railway
5	Nanjing Yangtze	3900	2x3	2010	Under Yangtze river
6	Hangzhou qinchun road	3100	2x2	2010	Under Qiantang river
7	Qingdao huangdao	8700	2×3	2011	Under sea
8	Guangdong Shiziyang	10800	2×1	2011	Under sea, High-speed (350km/h) railway


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Province
Tunnel bi-tubes de 8 km
Tracé du projet d'autoroute


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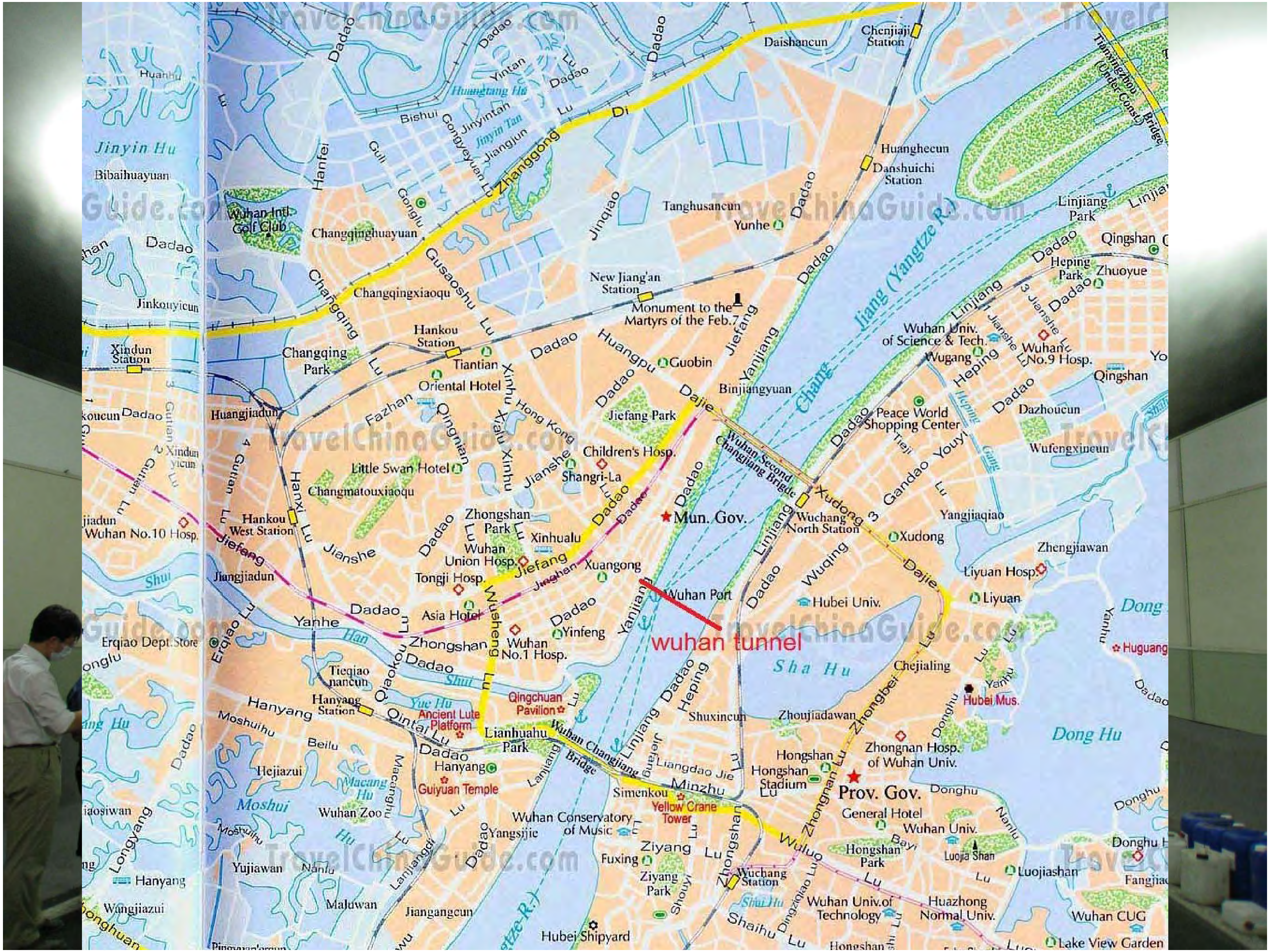

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wuhan tunnel
Chang Jiang (Yangtze R.)
Han Shui
Sha Hu
Dong Hu
Jinyin Hu
Huangtang Hu
Jinyin Tan
Tianxingzhou Bridge (Under Const.)
Wuhan Second Changjiang Bridge
Wuhan Changjiang Bridge
Zhanggong Di
Jiefang Dadao
Jiefang Dajie
Zhongshan Dadao
Jianshe Dadao
Hankou Station
Hankou West Station
Wuchang Station
Wuchang North Station
Hanyang Station
Xindun Station
New Jiang'an Station
Chenjiaji Station
Huanghecun
Danshuichi Station
Daishancun
Tanghusancun
Yunhe
Monument to the Martyrs of the Feb.7
Wuhan Intl Golf Club
Changqinghuayuan
Changqingxiaoqu
Changqing Park
Bibaihuayuan
Jinkouyicun
Tiantian
Oriental Hotel
Guobin
Binjiangyuan
Jiefang Park
Children's Hosp.
Shangri-La
Little Swan Hotel
Changmatouxiaoqu
Zhongshan Park
Xinhualu
Wuhan Union Hosp.
Tongji Hosp.
Xuangong
Asia Hotel
Yinfeng
Wuhan No.1 Hosp.
Wuhan No.10 Hosp.
Mun. Gov.
Wuhan Port
Huangjiadun
Jiangjiadun
Erqiao Dept. Store
Tieqiao nancun
Qingchuan Pavilion
Ancient Lute Platform
Lianhuahu Park
Hanyang
Guiyuan Temple
Wuhan Zoo
Yuejiawan
Yujiawan
Maluwan
Jiangangcun
Hubei Shipyard
Wuhan Conservatory of Music
Yangsijie
Yellow Crane Tower
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Hongshan Stadium
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Luojiashan
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Huazhong Normal Univ.
Wuhan CUG
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Fangjia
Donghu
Hubei Mus.
Huguang
Chejialing
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Hubei Univ.
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Zhengjiawan
Wufengxincun
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Qingshan
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Wugang
Heping Park
Zhuoyue
Linjiang Park


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Qingdao Tunnel
By 2011

The Challenge Tunnel in Future in China


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Qiongzhou
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400 km

2 The Fire and Reason in Tunnel

The crowd traffic in Wuhan tunnel

The Tunnel Fire in China

ChangYang tunnel in Hubei
Ten cars damaged , 2010

Wuxi tunnel in Jiangsu
24 people died, 2009

The Tunnel Fire in China

ChangYang tunnel in Hubei

20 car damaged and 290 people escaped, 2010

Jingjishan Tunnel in Zhejiang, 2006

The Tunnel Fire in China

Railway Tunnel in Sichuan,
After Wenchuan earthquick, 2008

The reason of the fire in Underwater Tunnel

- Short circuit of electrical equipment or cables in tunnels,
- Automobile engine burning
- Brakes burning (tires fire)
- Traffic accident
- Flammable materials loaded
- Etc.

Characteristics of the fire in underwater tunnel

- More passenger cars or bus.
- Smoke is at high concentrations, and its diffusion is slower
- Evacuation difficulties
- High temperature generated
- Rescue difficult.

How to control the fire ?

- Good Fire engineering design
- Suitable Fire Facilities
- Traffic control
- Perfect Fire management

3. Fire Fighting Measure in China

3 The Fire Fighting Measure in China

- 3.1 Ventilation Systems
- 3.2 The Main evacuation modes
- 3.3 Fire Suppression Systems
- 3.4 Accessorial Safety Facilities
- 3.5 Tunnel Structure and Equipment Fire Resistance Measures
- 3.6 Safety Management

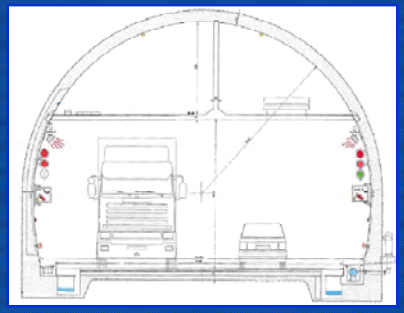
3 The Fire Fighting Measure in China

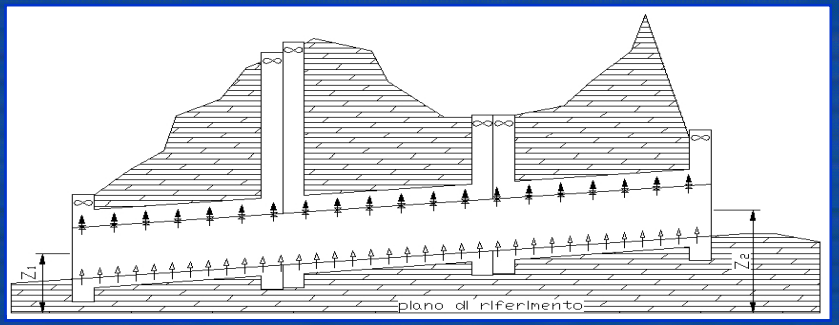
3.1 Ventilation systems

Transversal

- One or two ducts runs along the tunnel carrying fresh and foul air

-Fresh and foul air enter and leave the tunnel through openings located along the walls or the ceiling





Advantages

- Adequate for long tunnels
-Adequate for bi-directional traffic flow
-Constant fresh air supply
-Smoke is removed from the tunnel

Disadvantages

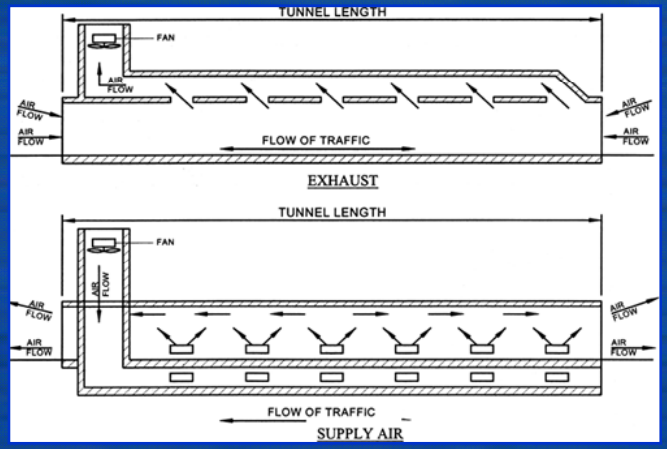
-High investment cost
-Inefficient in smoke control
-Control complicated
-Ventilation stations, ducts and big chimneys are always required

3 The Fire Fighting Measure in China

3.1 Ventilation systems

Semi-Transversal

- Semi-transversal ventilation systems use just one duct running along the tunnel; It can used for fresh air supply as well as smoke extraction.
-Fresh air supply or smoke extraction are achieved by openings located along the walls or the ceiling.



Advantages

- Smoke is removed from the tunnel
-Low maintenance costs
-Adequate for bi-directional tunnels
-Easy control strategy

Disadvantages

-Inefficient in smoke control
-High investment costs
-Ventilation stations, ducts and big chimneys are always required

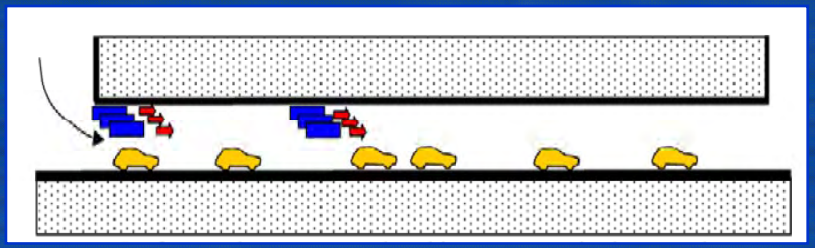
Semi-Transversal

Wuhan tunnel

3 The Fire Fighting Measure in China

3.1 Ventilation systems

Longitudinal



-Air movement is controlled by jet fans actions; the fans are installed on the tunnel ceiling

-Used in most tunnel in China from 1989

Advantages

- Ventilation system installation requires small spaces
-Low investment cost
-High efficiency for one-directional traffic flow
-smoke control is easier

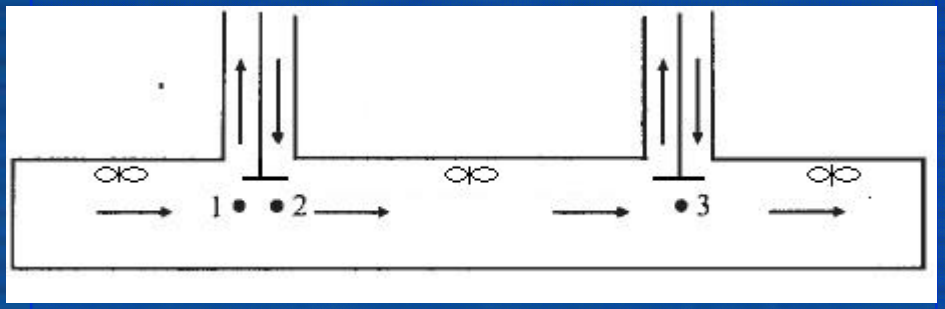
Disadvantages

- Jet fans installation is possible only in tunnels with high ceiling height
-Not adequate for bi-directional traffic flow
-High smoke emissions at both portals
-Smoke is not removed from the tunnel

3 The Fire Fighting Measure in China

3.1 Ventilation systems

Segmenting Longitudinal

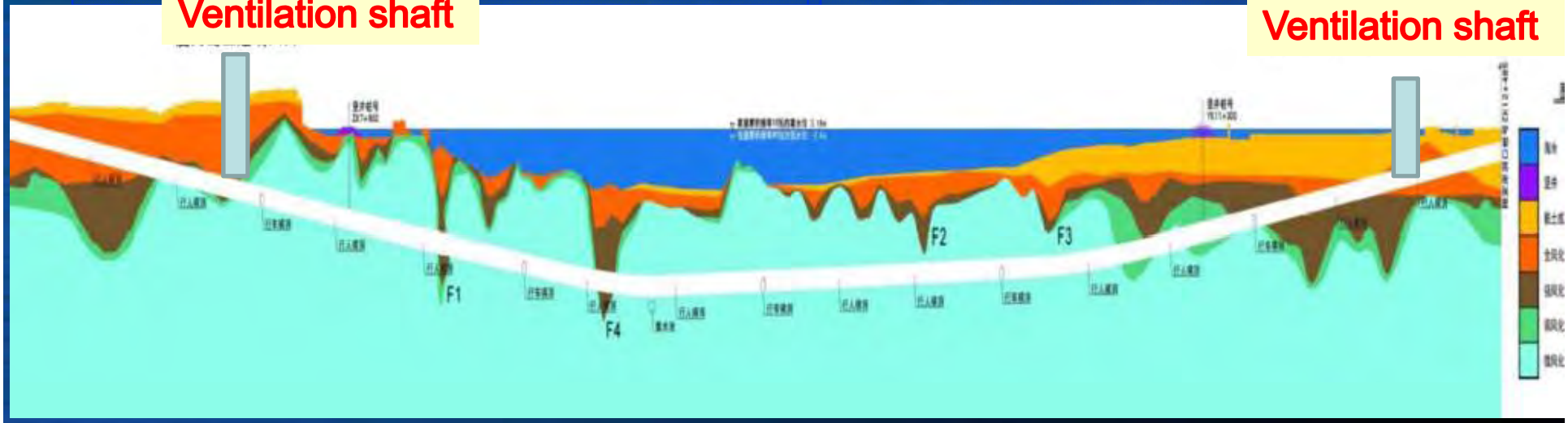


- Ventilation system installation requires small spaces
- Low investment cost
- -smoke control is easier
- Suitable for long tunnel with shafts

-Not adequate for smoke removed

Ventilation shaft

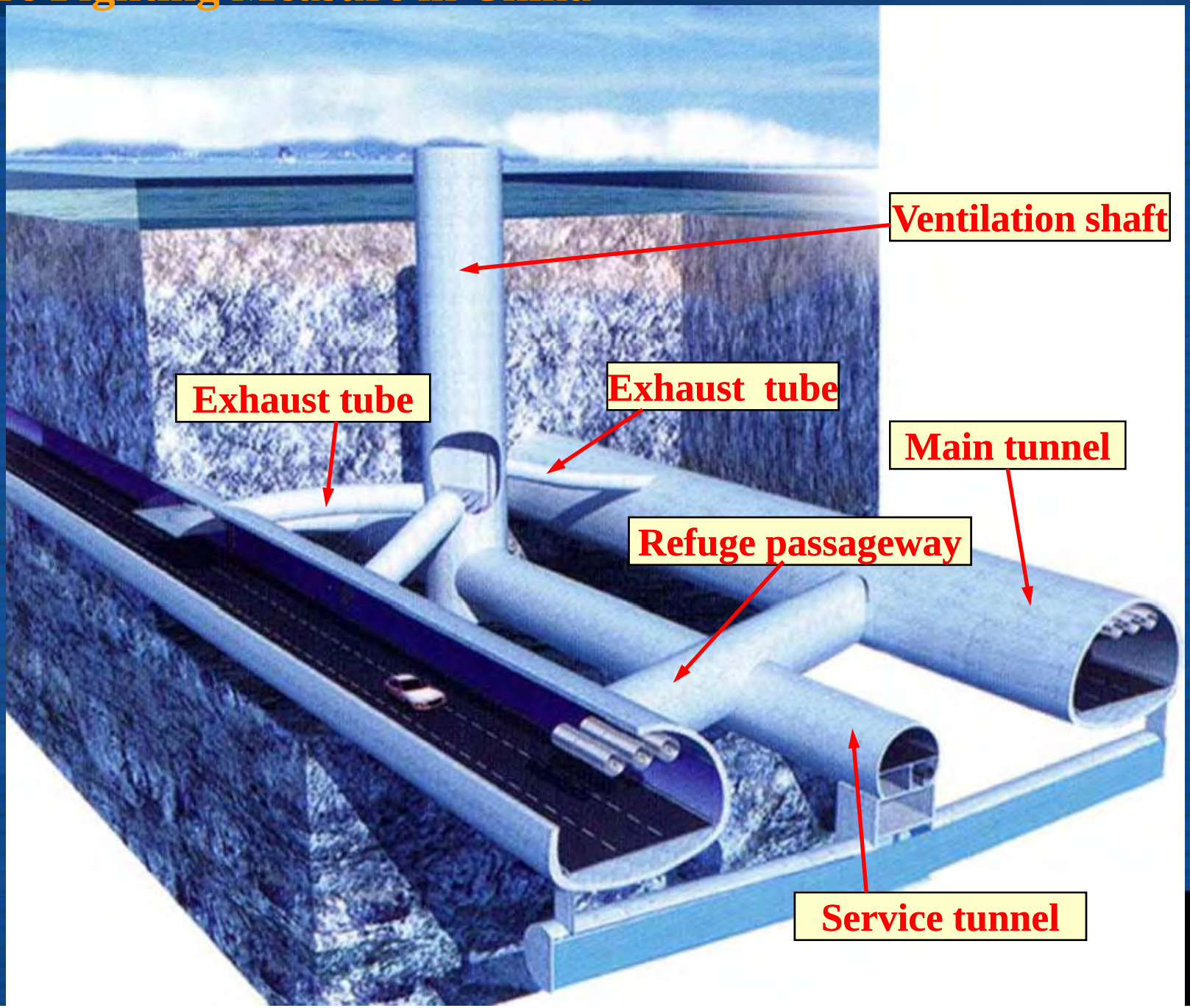
Ventilation shaft



Xiamen Xiangan tunnel Geological profile

3 The Fire Fighting Measure in China

Xiamen Xiang'an tunnel diagram



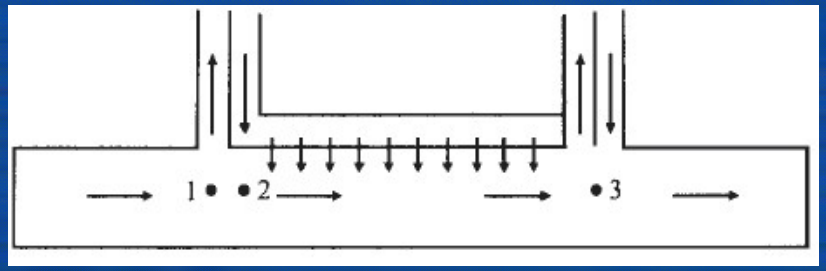
Xiamen Xiang'an Tunnel

3 The Fire Fighting Measure in China

3.1 Ventilation systems

Combined ventilation

- Both longitudinal ventilation and Semi-transversal ventilation systems use in a the same tunnel; each of them service one segment of tunnel.
-Fresh air supply or smoke extraction are achieved by openings located along the walls or the ceiling.



Advantages

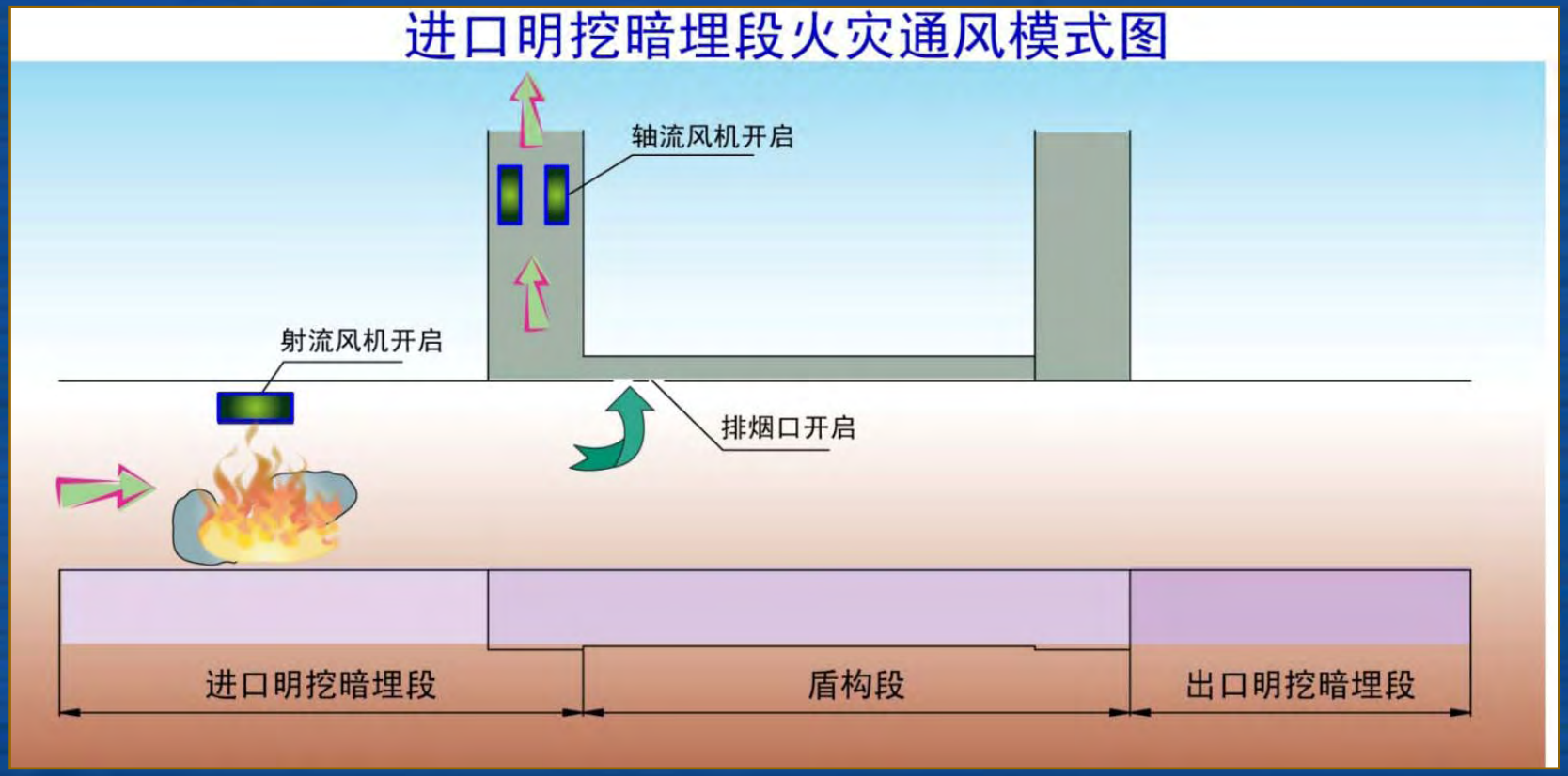
- Smoke is removed from the tunnel
-Low investment costs
-Adequate for bi-directional tunnels
- suitable for long tunnel

Disadvantages

-Inefficient in smoke control
-Control complicated
-Ventilation stations, ducts and big chimneys are always required

3 The Fire Fighting Measure in China

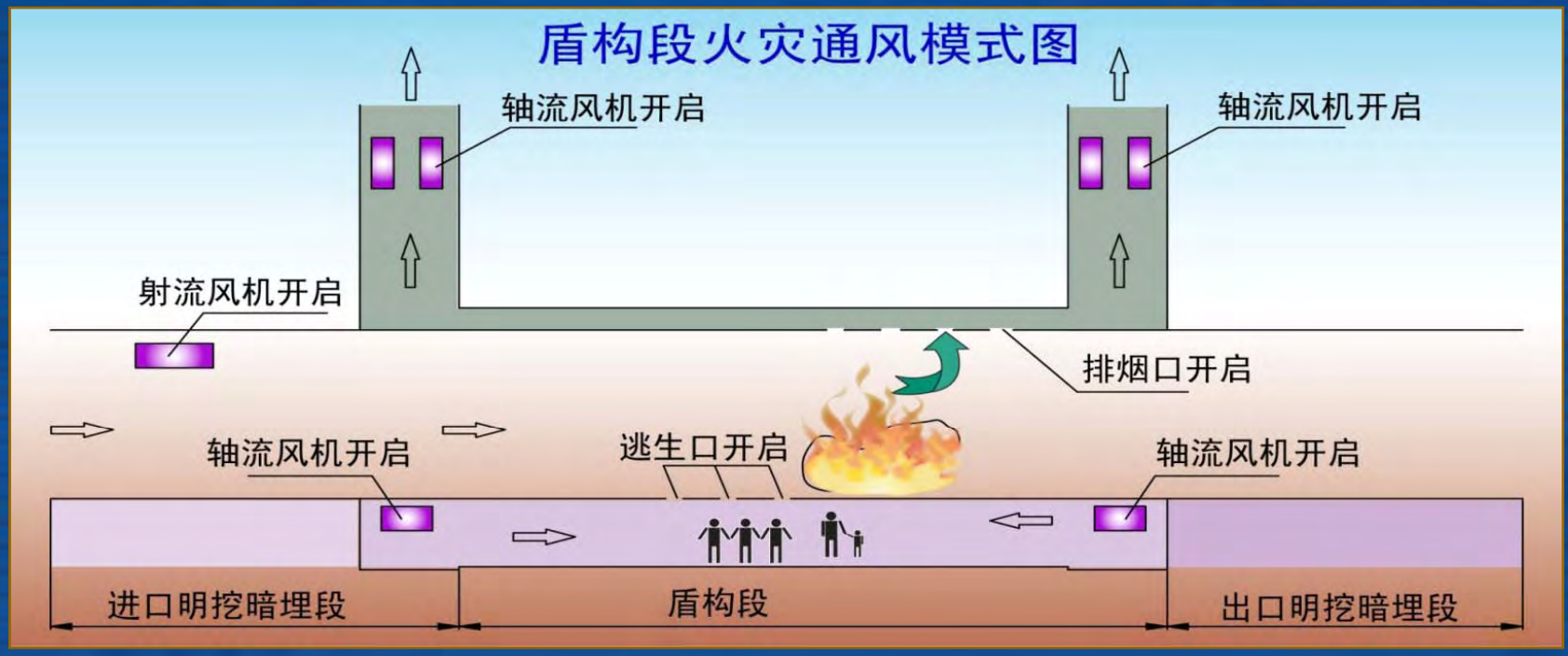
- Combined ventilation in Wuhan Yangtze tunnel



At the entrance segment of the Tunnel

3 The Fire Fighting Measure in China

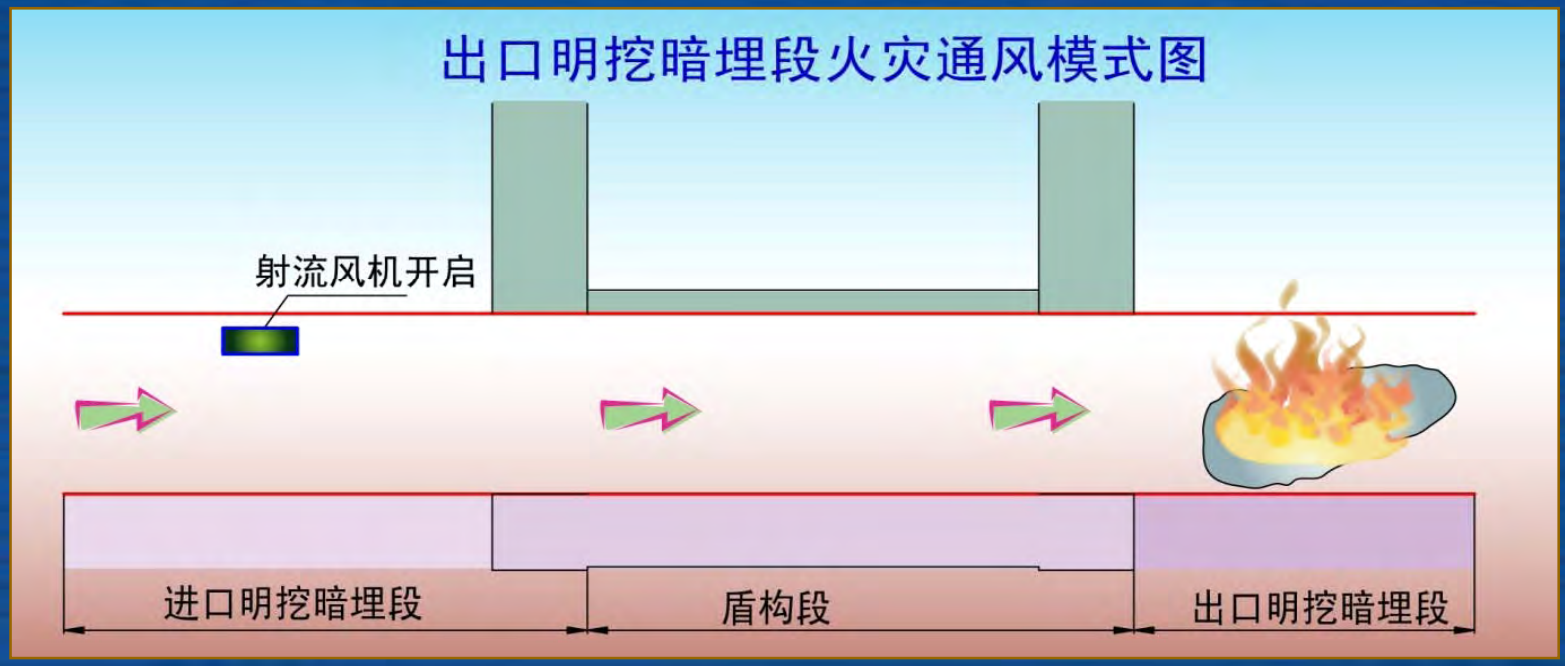
- Combined ventilation in Wuhan Yangtze tunnel



At the shield segment of the Tunnel

3 The Fire Fighting Measure in China

- Combined ventilation in Wuhan Yangtze tunnel



At the exit segment of the Tunnel

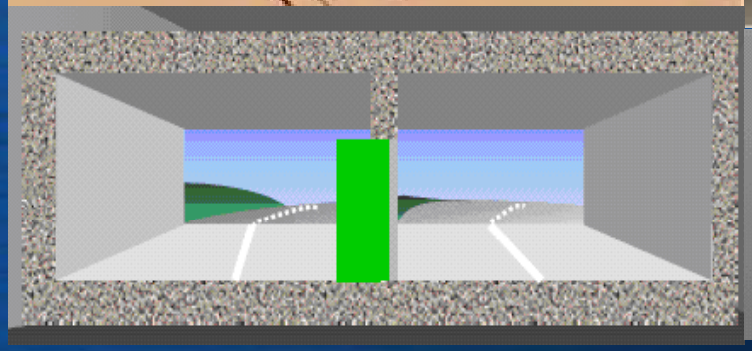
Ventilation system of long tunnels in China (selected)

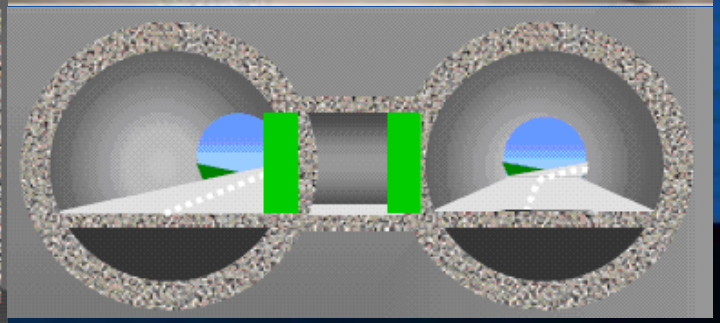
Erlangshan	4160	mountain	Semi- Transverse
Dapingli	12290	mountain	segmenting Longitudinal
Baojiashan	12100	mountain	segmenting Longitudinal shaft exhaust
ZhongnanShan	18400	mountain	segmenting Longitudinal shaft exhaust
Baiyun	7500	mountain	segmenting Longitudinal
Longtan	8700	mountain	segmenting Longitudinal
Yeshanguan	8150	mountain	segmenting Longitudinal
Kuocangshan	7900	mountain	segmenting Longitudinal centralized exhaust
Shanghai Yangtze river	8900	underwater	segmenting Longitudinal centralized exhaust
Wuhan Yangtze river	3200	underwater	Longitudinal ventilation centralized exhaust
Nanjing Yangtze River	3900	underwater	segmenting Longitudinal shaft exhaust
Xiamen Xiang'an Subsea	6050	underwater	segmenting Longitudinal shaft exhaust
Hangzhou Qingchunlu	3300	underwater	Longitudinal ventilation shaft exhaust
Qingdao Huangdao Subsea	7800	underwater	Longitudinal ventilation shaft exhaust

3.2 The main evacuation modes

1. Evacuation of double tube tunneling with cross-passageway

- Suitable for mountain tunnel with good geological conditions,
- little construction difficulty
- passengers using easier

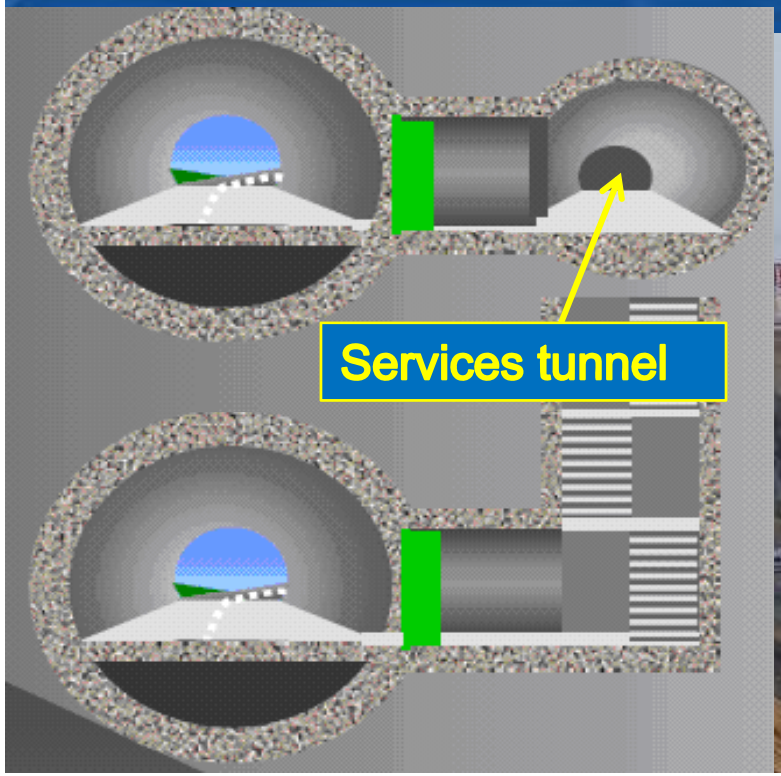




3.2 The main evacuation modes

2. Evacuation of horizontal accessional tunnel

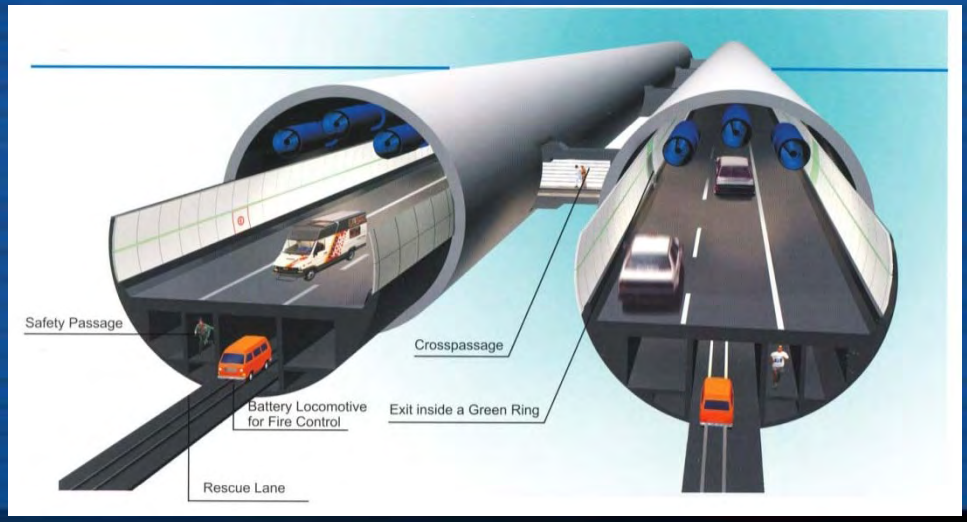
- Suitable for underwater or mountain tunnel with not too well geological conditions
- It can be as service passage of pilot tunnel for construction , and facilities maintenance

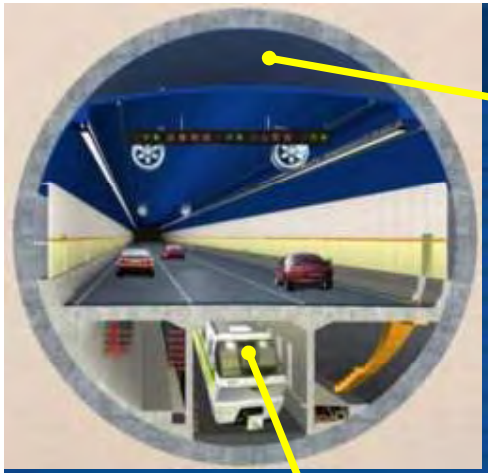


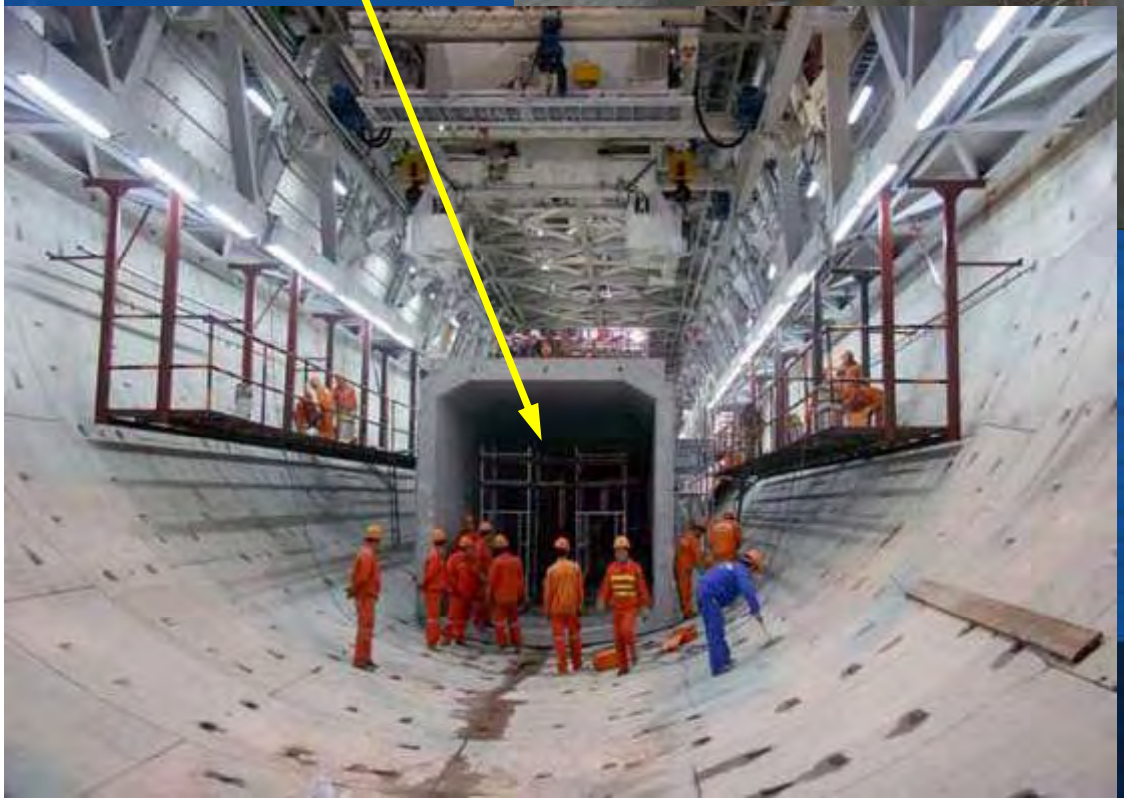
3.2 The main evacuation modes

3. Evacuation of longitudinal refuge passageway

- Utilize fully the vertical space below the tunnel
- Suitable for bad geological conditions or shield-constructed or some double deck tunnels
- Evacuation difficult for old or sick people, not adequate for the egress capacity





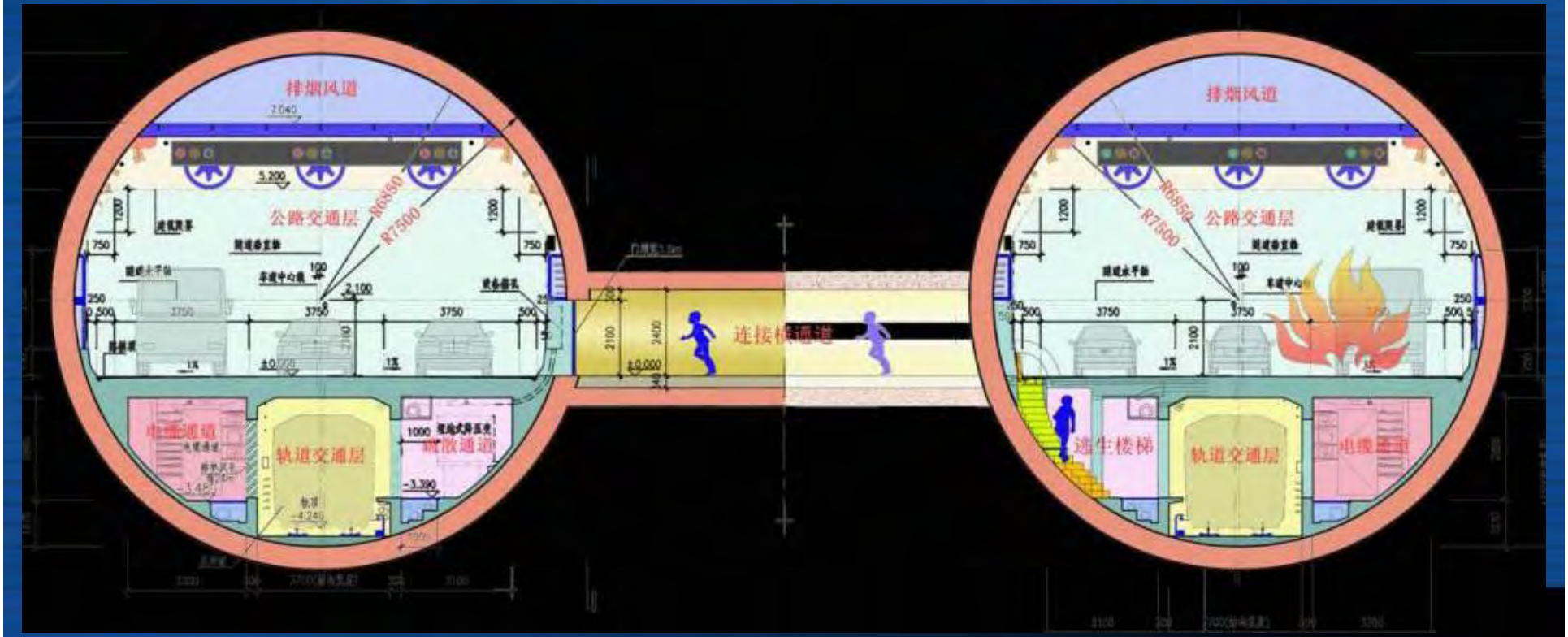


施工中

1 我国公路隧道建设基本情况

上海长江盾构隧道直径为15m，内径13.7m，盾构隧道段长7.47Km，是世界上最大直径的盾构隧道，也是世界上最长的水底隧道之一 。

隧道内上部为公路，下部为轨道和避难通道。



Some cases of the current underwater tunnel evacuation modes in China

Tunnel name	PROFILE	THE METHOD OF CROSS-PASSAGE
Shanghai Yangtze River	double deck tunnel, 8950m, double tube, 6 traffic lanes	Cross-passage in every 830m, a total of 8 passage, refuge stair in every 270m
Shanghai Dalian Road River	2565m，double tube, 4 traffic lanes	Every two passageways are in the distance of 400m
Shanghai Xiangyin Road	2606m，double tube, 4 traffic lanes	Every two passageways are in the distance of 500m
Nanjing Yangtze River	3900m，double tube, 6 traffic lanes	Refuge openings in every 80m, longitudinal refuge
Hangzhou Qiantang River	3042m，double tube, 4 traffic lanes	Refuge openings are in every 80m, longitudinal refuge
Wuhan Yangtze River	3295km，double tube, 4 traffic lanes	Refuge openings are in every 80m, longitudinal refuge
Xiamen Xiang'an Subsea	6500m under the sea	service channel connecting with the main tunnel, every two channels are in the distance of 300m

3.3 Fire Suppression Systems

1. Fire Extinguishers

- 4 fire extinguishers placed on both sides
- well-marked cabinets
- installed in combination with fire hydrant
- spacing < 50m.

2. Fire Hydrant System

- Minimum water flow rate is 20 L/s
- At least 10.0m in supply pressure
- spacing <50m
- Water tank is necessary

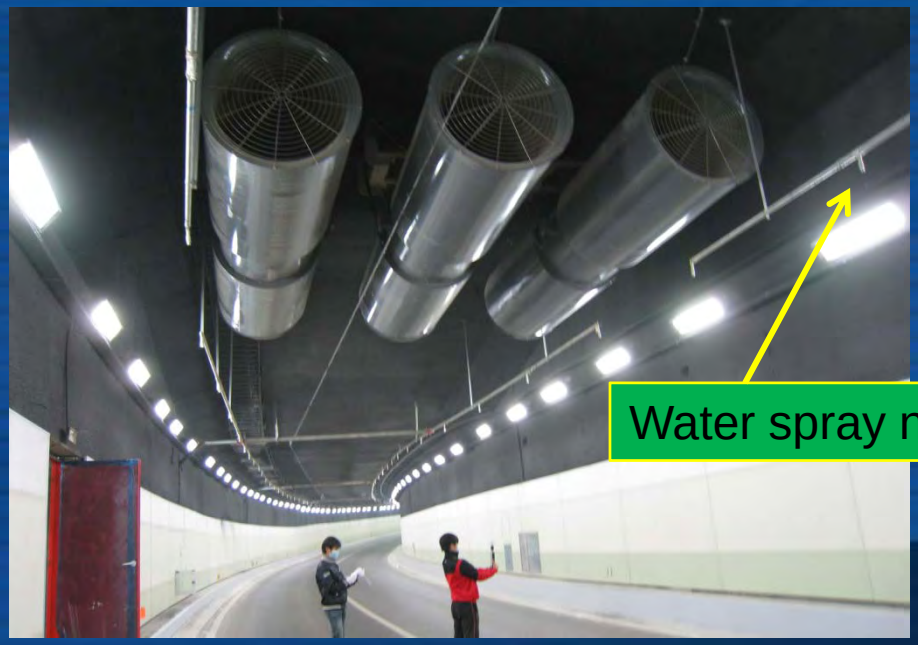
3. Water sprinkler extinguishes

Some worries

- Useless for fires inside carriages
- Cooling smoke, weak stratification
- High maintenance cost
- less visibility

Accept or not?

- Prevent fire growth and spread
- safe lives, It is not true for visibility
- Protect the structure
- Accepted comparing with the costs of the whole construction and fires disaster
- Usually water spray system used widely



The experiment of water spray system in Wuhan Tunnel

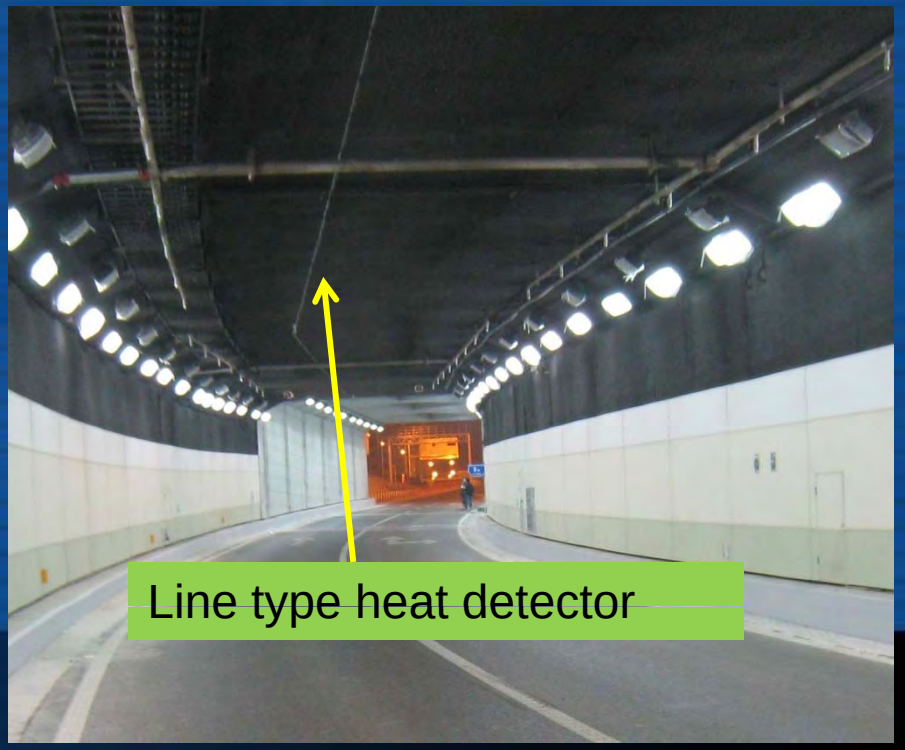
3.4 Other security facilities

1. CCTV

- Most long tunnel installed
- Spacing > 50-200m

2. Automatic fire detection system

- Line type heat detector
- Spot smoke detector



3.4 Other security facilities

3. Emergency Phone and Alarm

- Long tunnel installed
- Interval between 50 to 150m

4. Speaker and radio

- Long underwater tunnel

3.6 Safety Management

- Safety education and training
- Traffic control under normal
- Management of Dangerous Goods
- Good facilities maintenance

4 conclusion

- Good design for a underwater tunnel
- Reasonable selection of fire safety facilities
- Good management and maintenance
- Further fire safety research……
- More communication


More future…..

Thank you !