

**30th ITA - World Tunnel Congress  
22.-27-May 2004 in Singapore**

# **Latest Achievement and Perspectives in Tunnel Safety**

Alfred Haack, ITA, Lausanne, CH



# **Introduction**

## **Expected Development**

**Traffic**

**Worldwide Tunnelling**

**German Standards**

**European Directives**

**European Research Activities**

**Protection of Tunnel Lining**

**Fireproof Concrete**

**Upgrading of Tunnels**

**Closing**

**General  
starting situation**

**Modern industrial  
Countries need functioning  
infrastructures**









# Modern Infrastructures

**Must be:**

- fast
- reliable
- safe

**Need:**

- tunnels
- bridges





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# European traffic development after 1997

Passengers	until 2010	+20%
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	until 2030	+40%
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Goods	until 2030	+60%
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Vehicles	until 2020	+50%
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Driving  Stand still







# Quota of urban population

	1995	2015
Global and total	45%	55%
Developing countries	39%	50%
Industrial countries	75%	80%

 **Urbanisation**



# Urbanisation

Annually: + 60 Mio.

- 2015:
- ca. 10% of urban population in so called mega-cities  
(> 15 Mio. inhabitants)
  - 26 mega-cities,  
of them 18 in Asia



Tunnels for traffic  
and utilities





# Worldwide tunnelling

Europe 2100 km

(A) 260 km

(F) 150 km

(D) 450 km

(I) 200 km

(E, P) 500 km

(N,S,SF) 500 km

Asia 2350 km

South America 650 km

North America >650 km























# U-BAHN NÜRNBERG

6



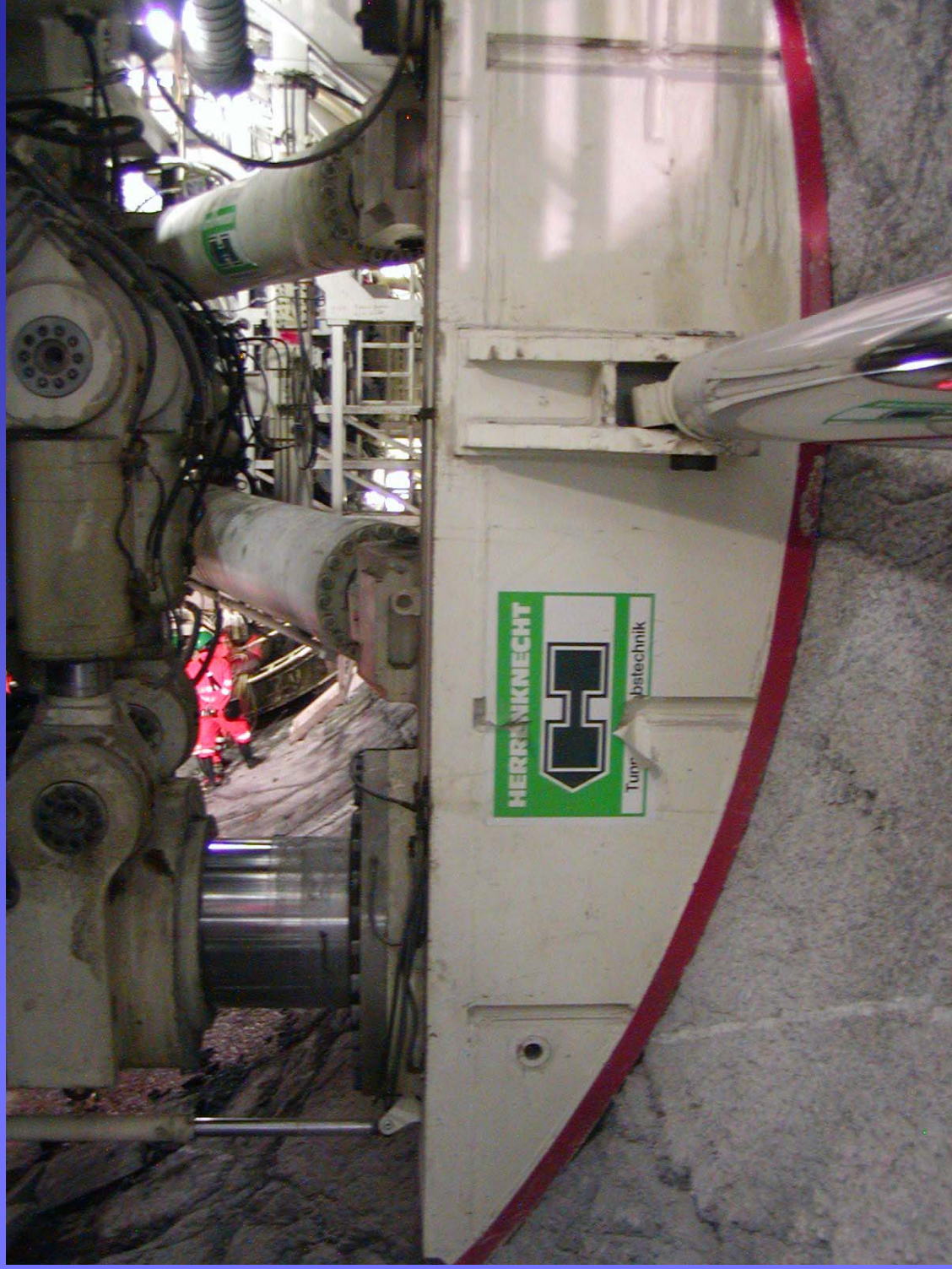




# Mega-Tunnels

Gotthard base-tunnel (CH)	57 km
Lötschberg base-tunnel (CH)	37 km
Brenner base-tunnel (A / I)	52 km
Mt. Cenis Tunnel (F / I)	52 km
Gibraltar Tunnel (E / MA)	35 km
Strait of Tartar (ROS)	
Bering Strait (ROS / USA)	





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# **RABT**

## **Guidelines for equipment and operation of road tunnels**

**(Richtlinie für die Ausstattung und den  
Betrieb von Straßentunneln)**

- **1985 first edition**
- **1994 first update**
- **2003 second update**



# **RABT 2003**

## **Objectives**

**Primarily:**

**Safety of users:**

- **Selfrescue**
- **Assisted rescue**

**Secondarily:**

- **Protection of  
infrastructure and  
private property**



# **RABT 2003**

## **Traffic related equipment (1)**

- **Minimum standard**
- **Basic standard**
- **Extended standard**

# **RABT 2003**

## **Traffic related equipment (2)**

### **Minimum standard**

**$< 400$  m**

**$\leq 15.000$  veh / d and lane**

**$\leq 80$  km/h**

**for all tunnels obligatory**

# **RABT 2003**

## **Minimum standard**

- **Hight indication if  $h < 4.5$  m**
- **If required yellow flash light at entrance**
- **Restriction of speed**
- **„No Passing“ sign:**
  - **general in case of bi-directional traffic**
  - **for trucks in case of one-way traffic**
- **Inside tunnel no traffic signs**

# RABT 2003

## Traffic related equipment (3)

### Basic standard

$400 \text{ m} < l < 2000 \text{ m}$

$\leq 15.000 \text{ veh / d and lane}$

$\leq 80 \text{ km/h}$

# **RABT 2003**

## **Basic standard**

### **In addition to minimum standard**

- **Traffic data logging for early recognition of interferences and emergencies**
- **Additional varying traffic signs at portal and inside the tunnel**
- **Physical barrier and video camera at portal**
- **Indication of traffic radio**

# **RABT 2003**

## **Extended standard**

### **In addition to basic standard**

- **Permanently illuminated traffic signs**
- **Additional varying traffic signs**
- **Varying signposts**

**Required in rare cases only**



# **RABT 2003**

## **Emergency exits**

**Tunnel length  $\geq 400$  m: each  $\leq 300$  m**

- **to the outside**
- **directly into the parallel tube**
- **through a crosspassage \* into a parallel tube**
- **to an emergency shaft \***
- **to an escape drift \***

**\* Developed as a separate smoke and fire section**

# RABT 2003

## Escape ways

- on both sides of the tunnel,  $\geq 1$  m wide,  $\geq 2,25$  m high
- kerbstone 7 cm ( $\leq 25$  cm )

## Emergency telephone

- for tunnel length  $\geq 400$  m: each  $\leq 150$  m
- for noise absorption installed in an accessible box
- not fireproof

# RABT 2003

## Tunnel drainage

### Slot drain

- 100 l / s
- each 50 m fireproof bulkhead
- Connection with main drain via syphon and a diving wall

### Retention basin

- 100 m<sup>3</sup> (72 m<sup>3</sup> extinguishing water + 30 m<sup>3</sup> volume)



# **Railways**

## **EBA – Rİİ**

**Structural and operational demands for the  
protection against fire and catastrophes  
in railway tunnels; 1997**

**( Anforderungen des Brand- und  
Katastrophenschutzes an den Bau und  
Betrieb von Eisenbahntunneln; 1997 )**



# EBA - Rii

- Lateral escape way with handrail for each track
- Width of escape way: 1.2 m ( $\geq 0.8$  m)
- Spacing of emergency exits:  $\leq 1000$  m
- Emergency exit as:
  - Portal
  - Drift to outside area
  - Smaller parallel tunnel
  - Shaft  $\leq 60$  m high
    - ( if  $\geq 30$  m: a lift is needed )

# EBA - Rii

- Emergency lighting  $\geq 0.5$  lx  
each 125 m on both tunnel sides
- Escape route sign each 25 m
- Road access to portals and each exit
- Extinguishing water pipe for  
delivery of 800 l/min and with  
hose connection each 125 m
- Emergency telephone at portals and  
emergency exits





# **Subway Systems**

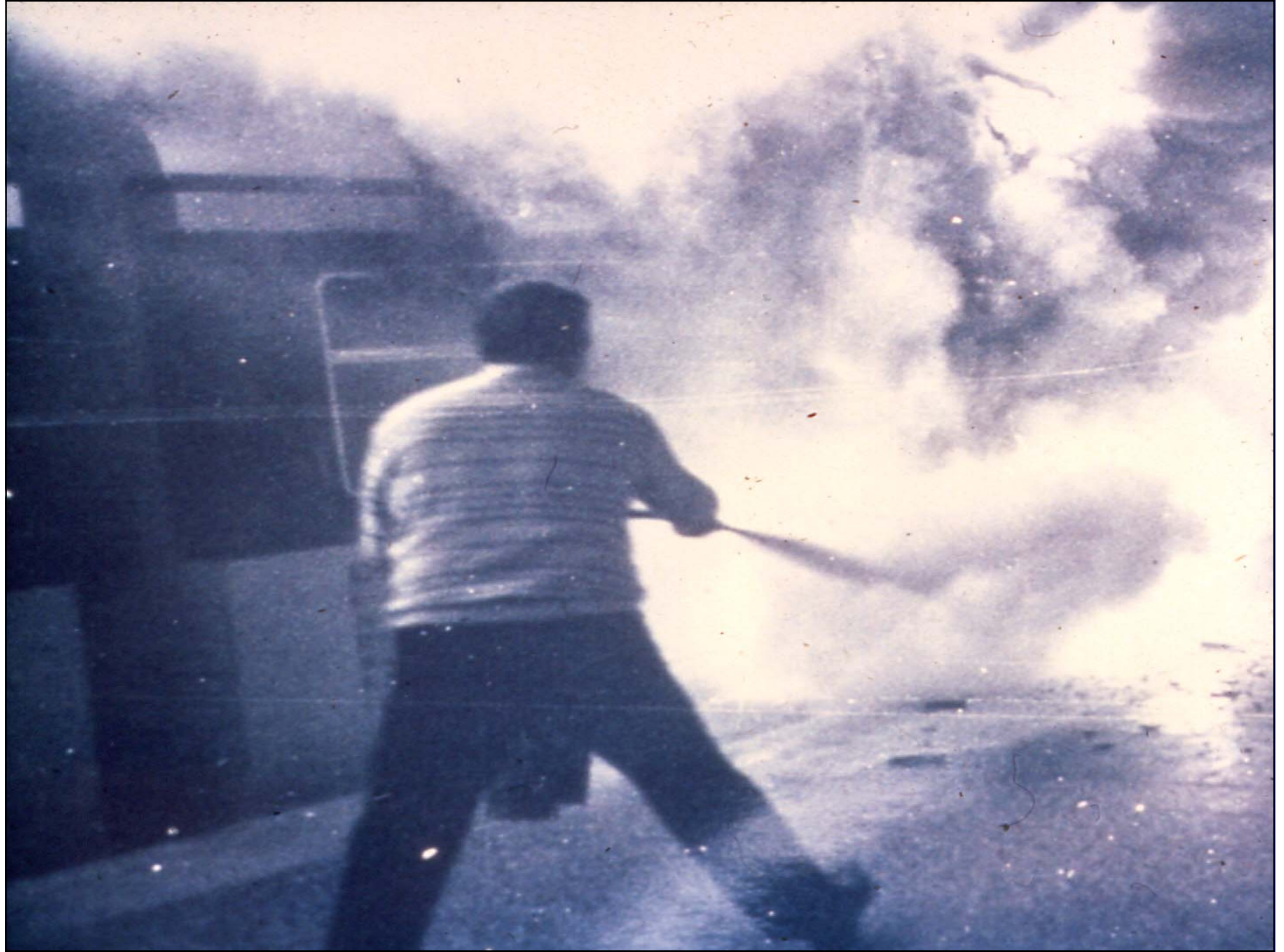
## **BOStrab**

**Guidelines for Construction and Operation of  
Trams and Subways; 12.1987**

**BOStrab – Tunnel Construction Guidelines;  
4.1991**

**( Verordnung über den Bau und Betrieb der  
Staaßenbahnen; 12.1987 )**

**( BOStrab – Tunnelbaurichtlinien; 4.1991 )**



# Subway

- **basic rule:**  
**2 independent exits**
- **in old facilities with**  
**not acceptable conditions:**  
**improved escape way**  
**through route tunnel**





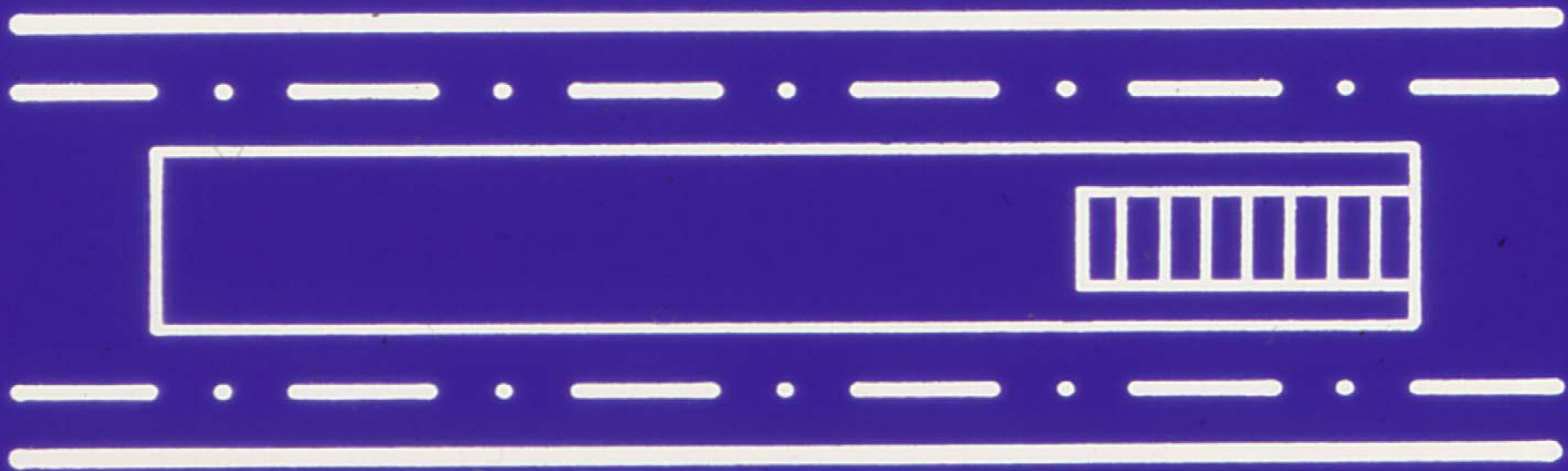


# Subway BOStrab

emergency exit distance  $\leq 600$  m



# Subway Central Platform

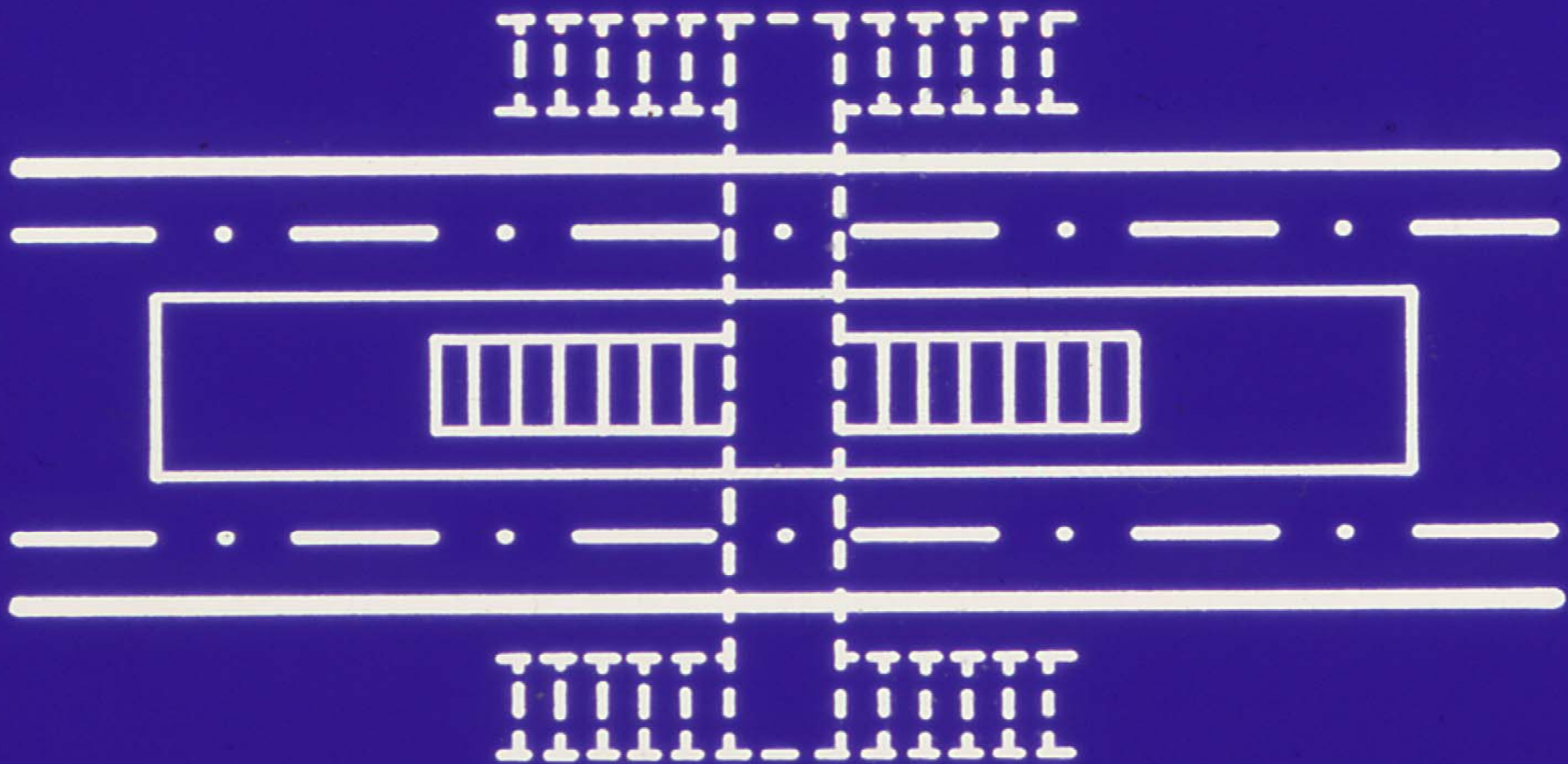


**1 direct exit at end**





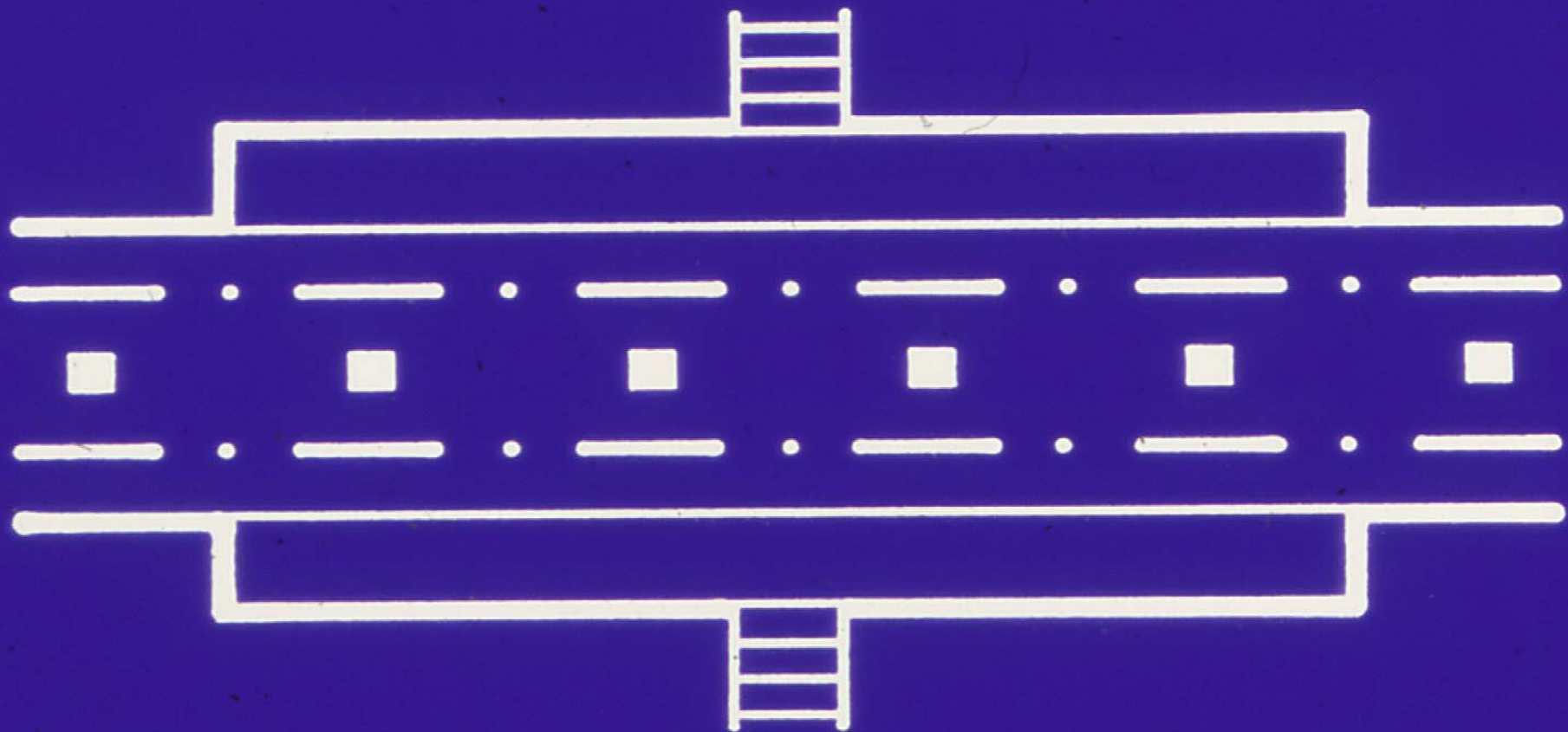
# Subway Central Platform



1 indirect exit in middle



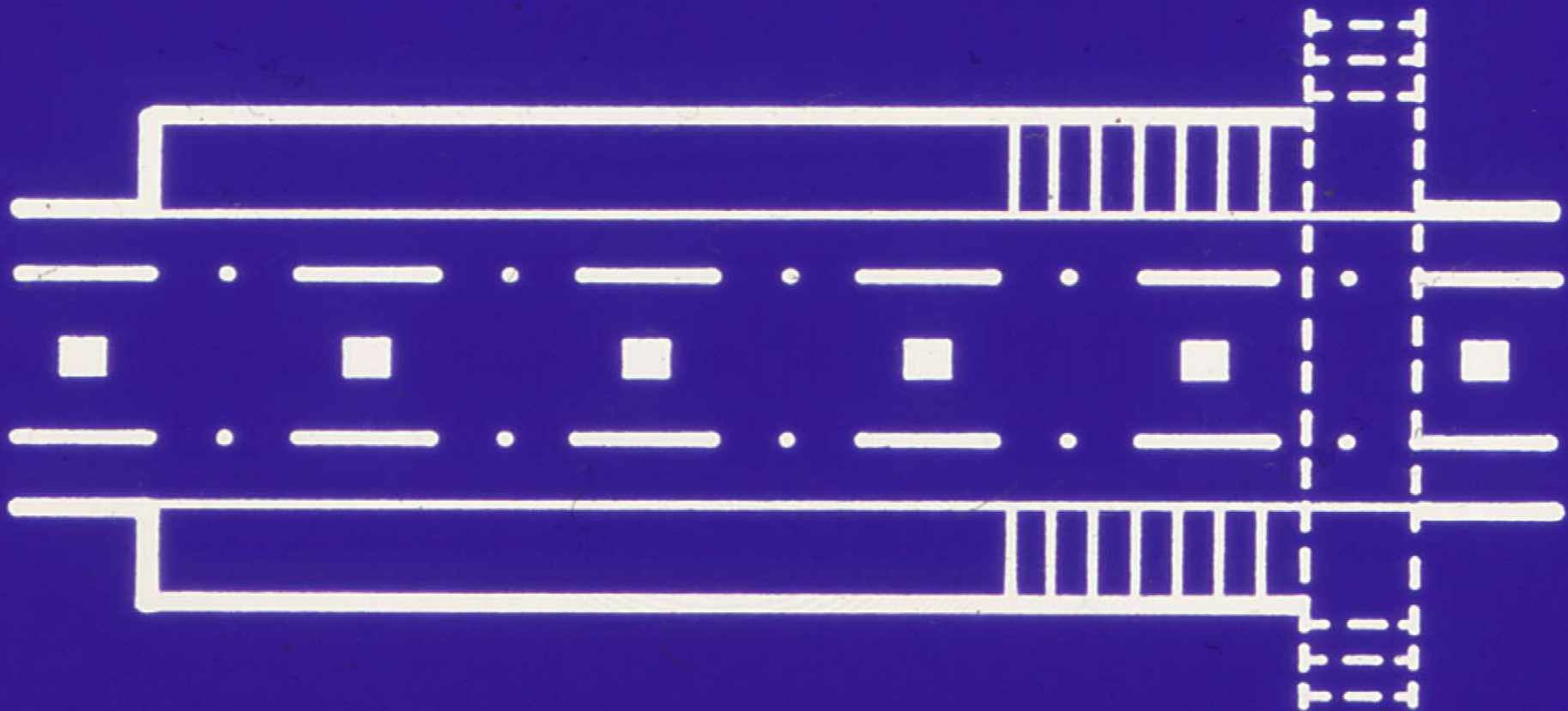
# Subway Side Platforms



**2 direct or indirect exits in middle  
simple traffic situation**



# Subway Side Platforms

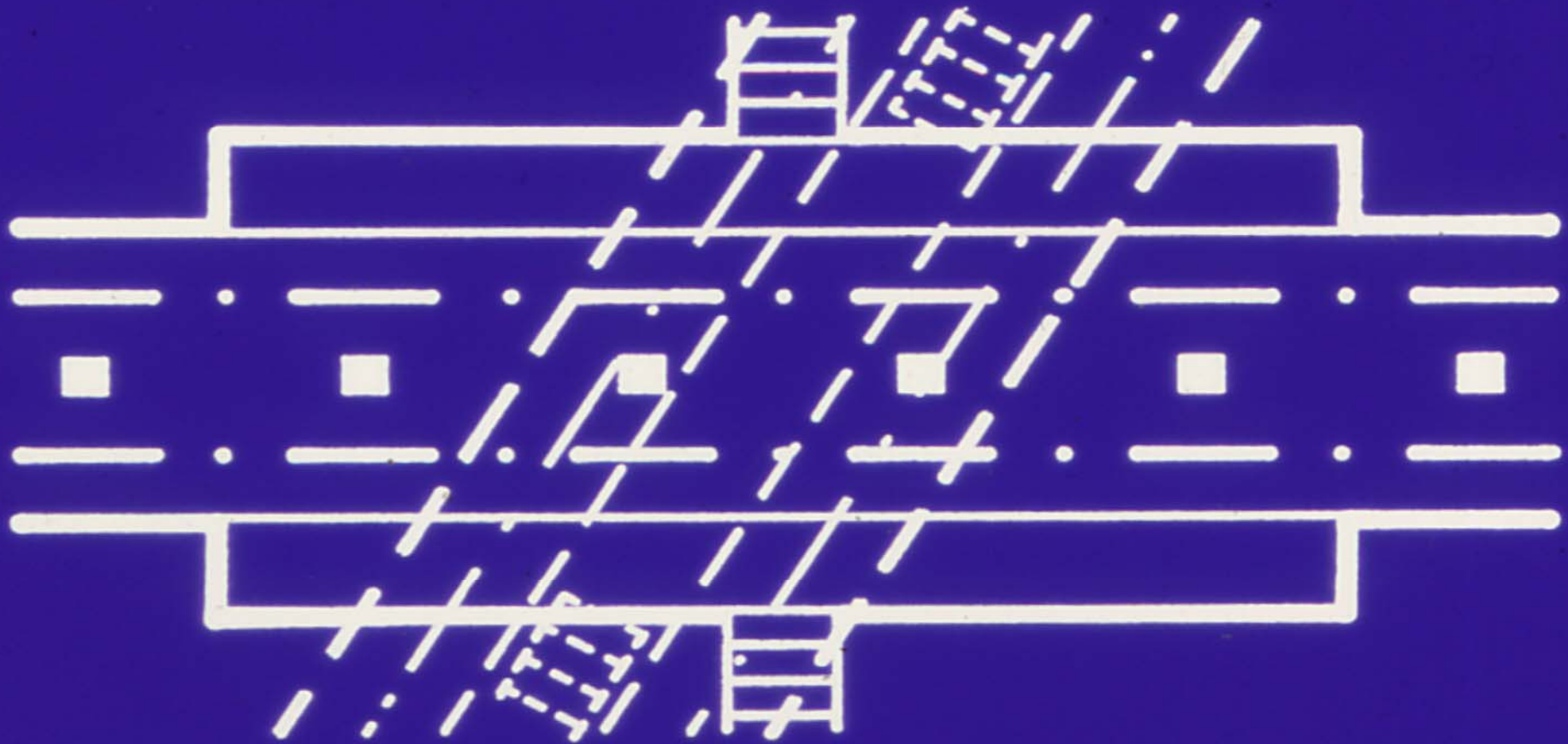


**2 indirect exits at end**





# Subway Side Platforms



**2 direct or indirect exits in middle  
crossing station**



# **Upgrading Metro Tunnels**

- **A-staircases**
- **V-staircases**
- **location of staircases**
- **escape through tunnel**
- **smoke control**



# Subway

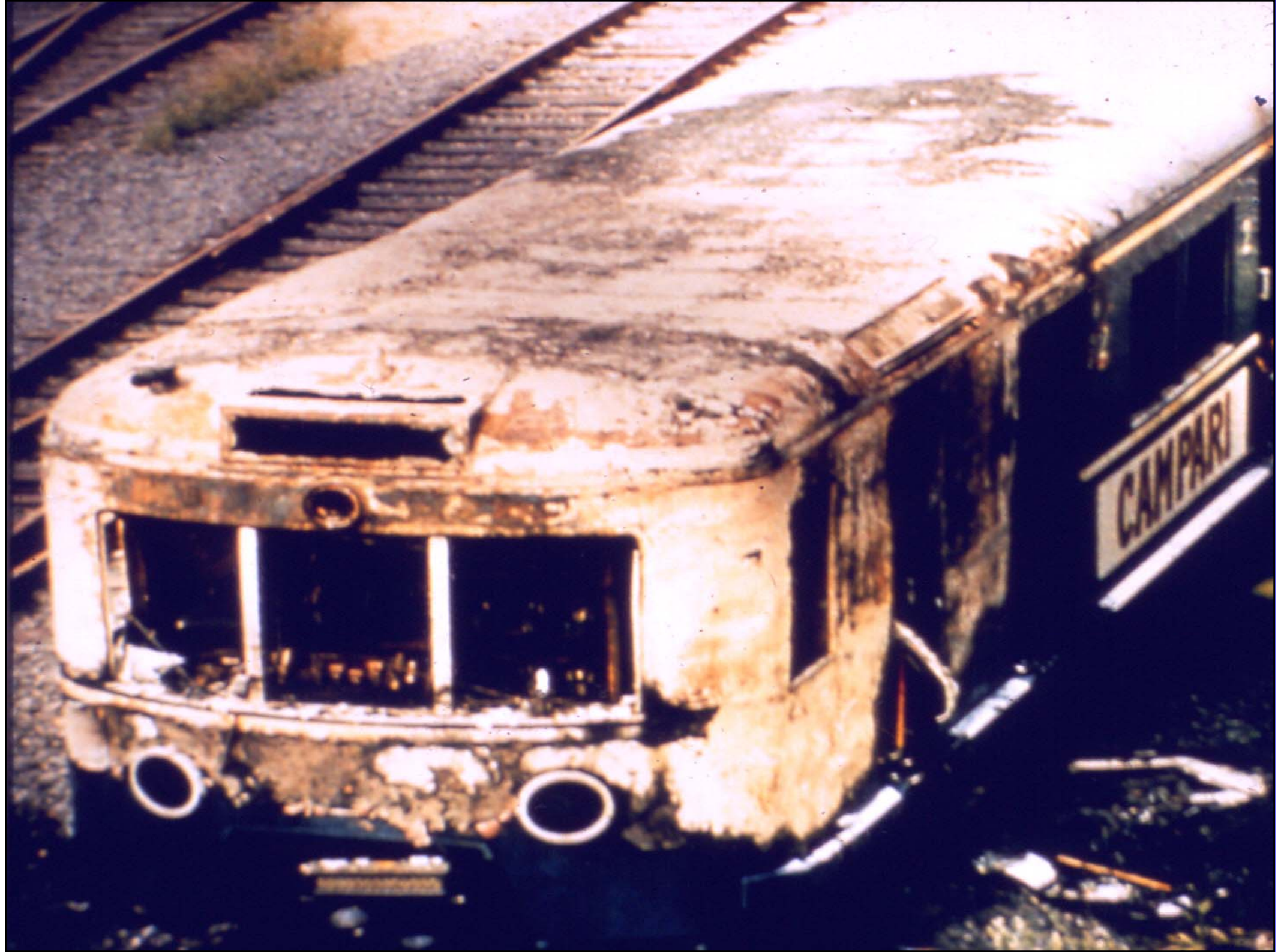
- **escape way through route tunnel  $\leq 150$  m**
- **well indicated**
- **emergency light  $\leq 1$  m high**
- **wood boards in track or catwalk with handrail**
- **immediate cut-off of electrical power**



# **Influence on damage by type of car body**

- steel**
- aluminium**
- plastic**

**(downwards increase of  
damage)**











# Fire Load in Rail Coaches

50 – 80 kg/m<sup>2</sup> ( wood equivalent)

For comparison:

- Housing: 30 – 60 kg/m<sup>2</sup>
- Department ware house: 100 kg/m<sup>2</sup>







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# **European Directive**

## **April 2004 (1)**

**Main reasons for  
accidents:**

- **wrong actions of users**
- **insufficient safety equipment of the  
road network**
- **technical defects in the vehicles**
- **problems regarding the load**

# **European Directive**

## **April 2004 (2)**

### **Main Objectives:**

- **avoiding critical incidents  
endangering persons, environment,  
and tunnel**
- **mitigation of possible effects  
especially in case of car fires**





# **European Directive**

## **April 2004 (3)**

### **Main objectives:**

- **10 to 15 min. decisive for escape**
- **all tunnels  $\geq 500$  m long**
- **4 most important safety criteria:**
  - **road infrastructure**
  - **tunnel operation**
  - **vehicles**
  - **drivers**

# **European Directive**

## **April 2004 (4)**

**Estimated financial  
demands:**

- a) 2.5 billion EURO for minimum measures (traffic restriction, only few structural upgradings)**
- b) 6 billion EURO upgrading of all tunnels to the standard for new tunnels**

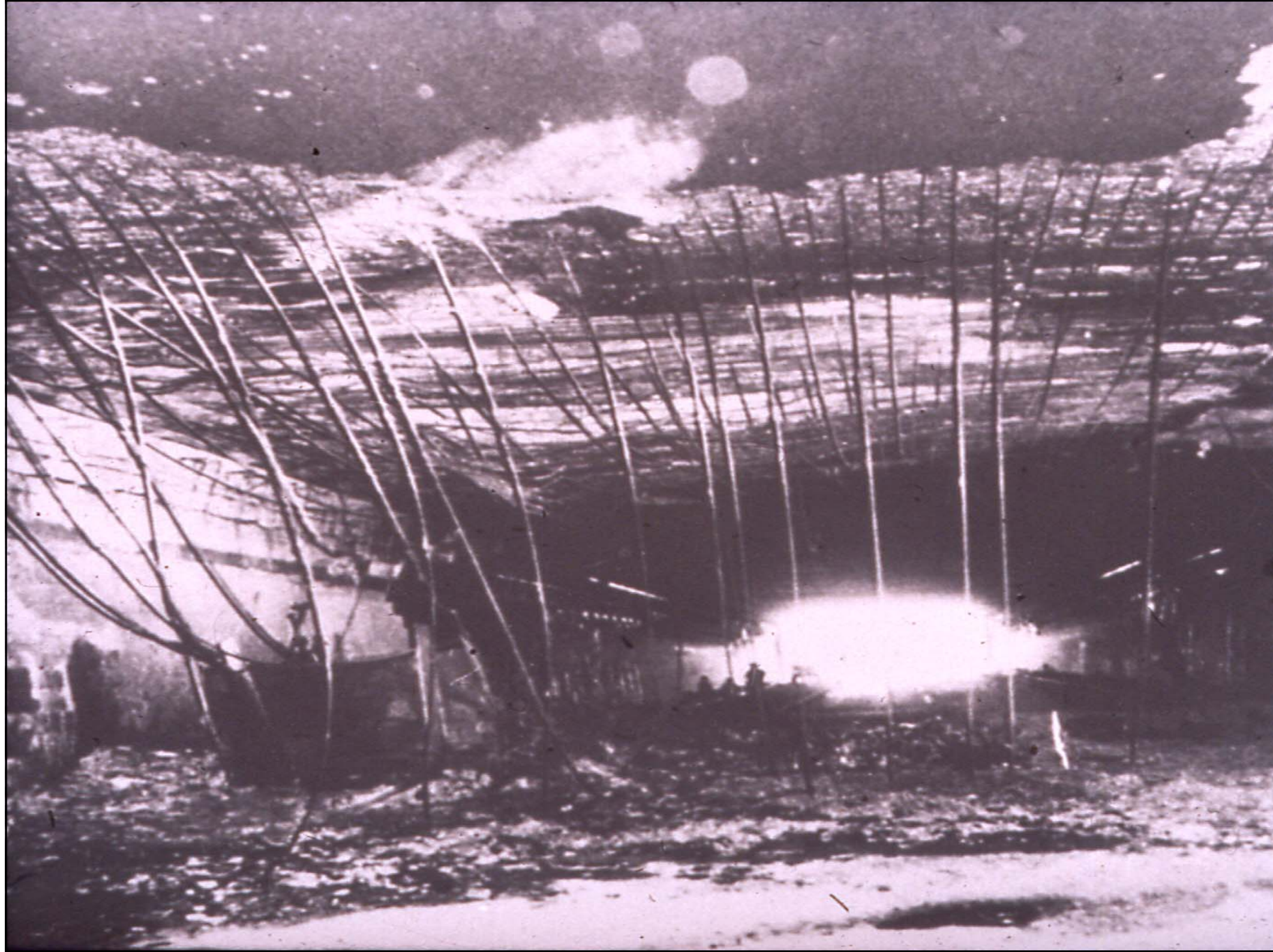


# **European Directive**

## **April 2004 (5)**

### **Benefit of the upgradings planned**

- **by mitigation of the dimensions of damage and avoiding accidents  
ca. 200 Mio. EURO / year**
- **by avoiding temporary tunnel breakdowns and traffic diversions:  
300 – 450 Mio. EURO / year taking  
Italy only as an example**



# **European Directive**

## **April 2004 (6)**

**Realisation in 2 steps:**

- a) short- and medium-term: minimum standards according to guidelines**
- b) medium- and long-term:  
shifting the long-distance goods transport more and more onto rail**





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# Remarkable and important initiatives in FP5 of EC



DARTS

Durable And Reliable Tunnel  
Structures



FIT

Fire In Tunnels



UPTUN

UPgrading of TUNnels



SAFE-T

SAFEty in Tunnels

...and others



**Current  
Knowledge  
2001-2004**



**D.A.R.T.S.**

**New tunnel  
(design)  
2001-2003**



**UPTUN**

**"linked projects"  
National &  
International**

**Guidelines  
Legislation  
2002-2004**

**"linked  
projects"**

**Safety measures  
Existing tunnels  
2002-2005**



# European Research

**(1) Upgrading of tunnels is often neglected**

**(2) New concepts are mostly related to future tunnels**



# European Research

## Focus on:

- (1) Fire detection technologies**
- (2) Mitigation measures**
- (3) Influencing human response**
- (4) Protection of the tunnel structure**
- (5) Socio-economic impacts**
- (6) Dissemination of upgrade know-how**





# European Research

- (1) Consortium of 41 partners from 18 countries**
- (2) Term of project: 4 years  
(September 2002 to August 2006)**
- (3) Costs of the project: approx. 12 million Euro**
- (4) Funding by EC: approx. 6 million Euro**
- (5) Man-months in total: approx. 950**

**Workshop Darts-Fit-UPTUN**  
**Prague**  
**04.-06.02.2004**

**Safe and Reliable Tunnels -  
Innovative European  
Achievements**

# Worldwide international discussion

ITA

International **T**unnelling  
**A**ssociation

PIARC

World Road Association

UIC

**U**nion **I**nternationale des  
**C**hemins de Fer

UITP

**U**nion **I**nternationale des  
**T**ransport **P**ublic Urban et  
Regionaux

UNECE

**U**nited **N**ations **E**conomic  
**C**ommission for **E**urope



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# Fire protection of tunnel lining

- mineral cladding / mineral plaster
- large covering and additional reinforcement
- perforated steel plates with foaming coating
- fire proof concrete

⇒ Heating up of bars  $< 300^{\circ} \text{ C}$

⇒ Minimization of spalling







# **Additional Reinforcement**

**set up towards the fire affected side  
of the concrete lining for reducing the  
spalling**

**Disadvantages:**

- increasing costs**
- thicker lining**
- additional working step**









# Mineral Boards and Plaster (1)

## Disadvantages:

- larger excavation cross section needed
- longer construction time
- risk for absorption of seepage water causing loss of thermal insulation capacity
- risk of local falling down due to increase of dead weight



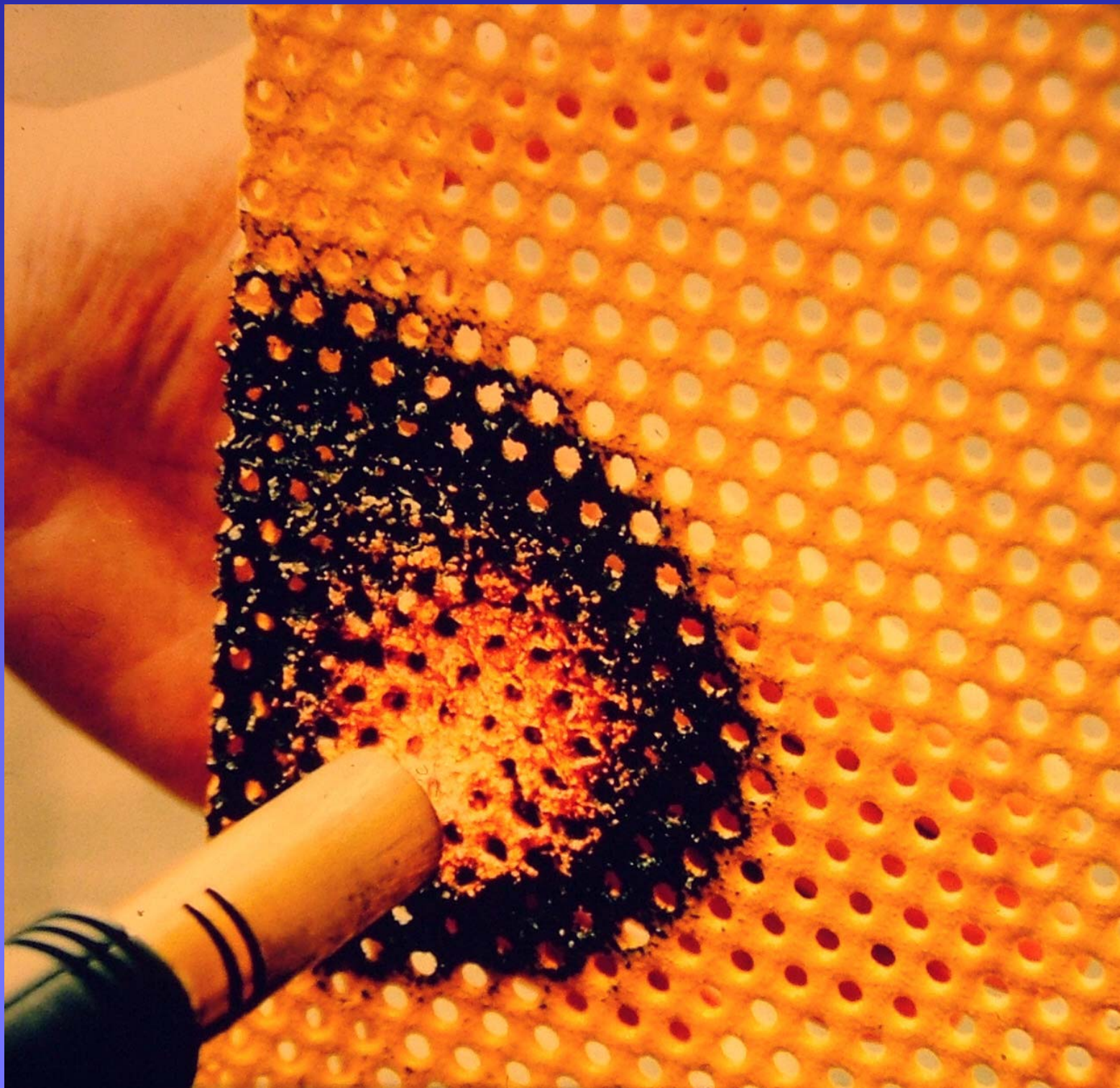




# Mineral Boards and Plaster (2)

## Disadvantages:

- risk for corrosion of board fasteners
- no visual access of lining for inspection
- renewal after 25 to 30 years: 3 to 4 times during life cycle of a tunnel
- risk of partial falling down due to sucking load of fast trucks









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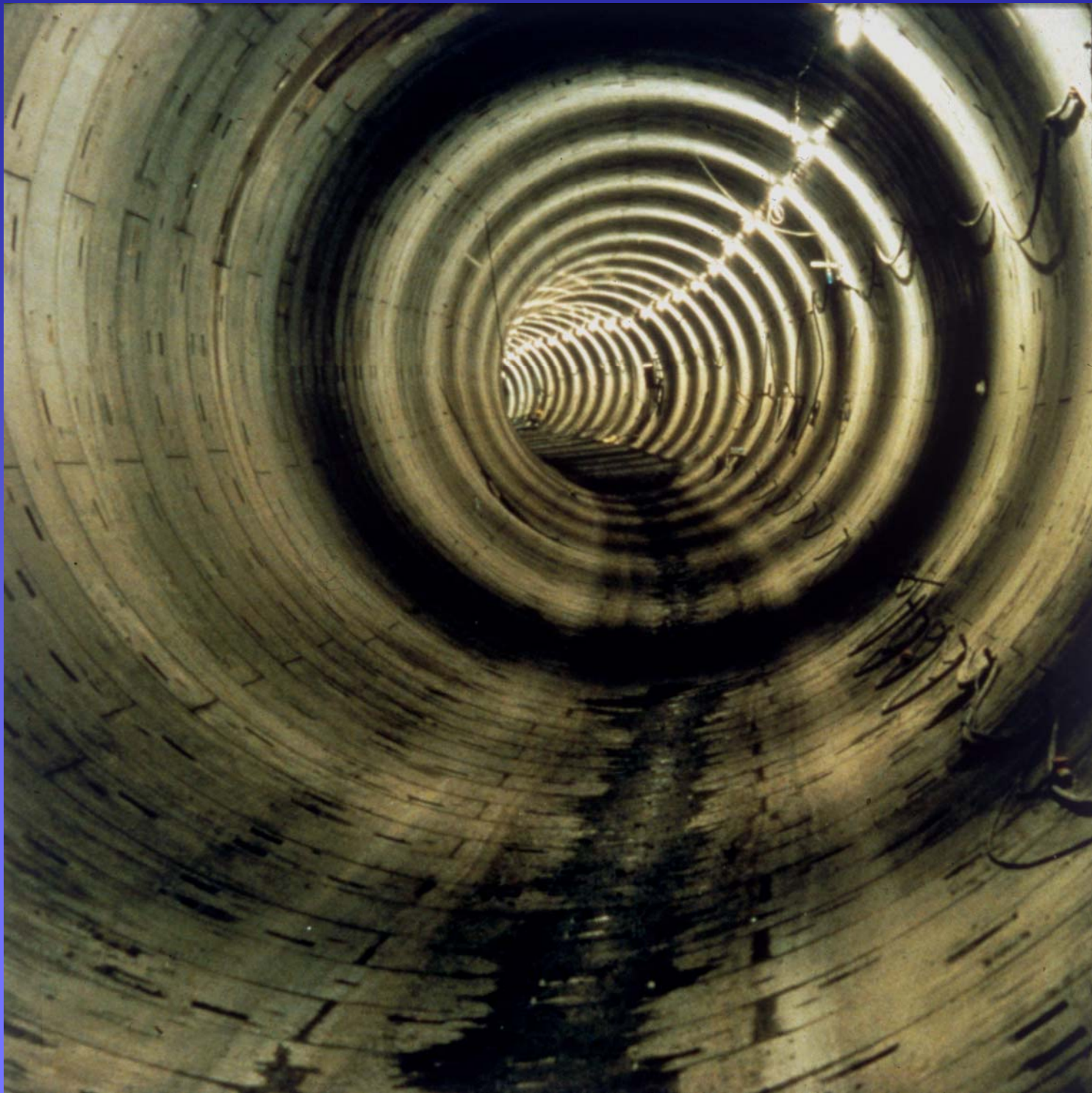
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# Fire proof Concrete: advantages for **execution**

- omission of fire proof cladding
- smaller excavated cross section
- shorter construction time
- sufficient fire protection already during execution
- simpler assembling of tunnel installations

# **Fire proof Concrete:** advantages for **operation**

- **free access for tunnel inspection**
- **life cycle like for the tunnel**
- **no problems caused by sucking and pressure loads of fast trucks**
- **problem-free tunnel cleaning**
- **no problems with water seepage**
- **low damage in case of vehicle collision**
- **nearly no spalling in case of fire**



# Fire proof Concrete

**Necessitates a special mix:**

- **maximum core group of aggregates consists of basaltic gravel**
- **quarzite, no chalky aggregates**
- **addition of 3 kg/m<sup>3</sup> Polypropylene fibres**
- **quality class  $\geq$  C 25/30**

# Fire proof Concrete

- several years research work by:  
Hochtief AG ( contractor )  
TU Braunschweig, Germany  
STUVA, Cologne, Germany
- fire test 1200 C° over 90 minutes
- no severe spalling, locally restricted only
- spalling depth less than 10 mm

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# Examples for Upgrading Tunnels

Fourth Bore of River Elbe Tunnel,  
Hamburg, Germany

Bosruck Tunnel, Austria

Mont Blanc Tunnel, France

Frejus Tunnel, France

April 2002



























*Tunnel du Mont Blanc*



**11,6 km**













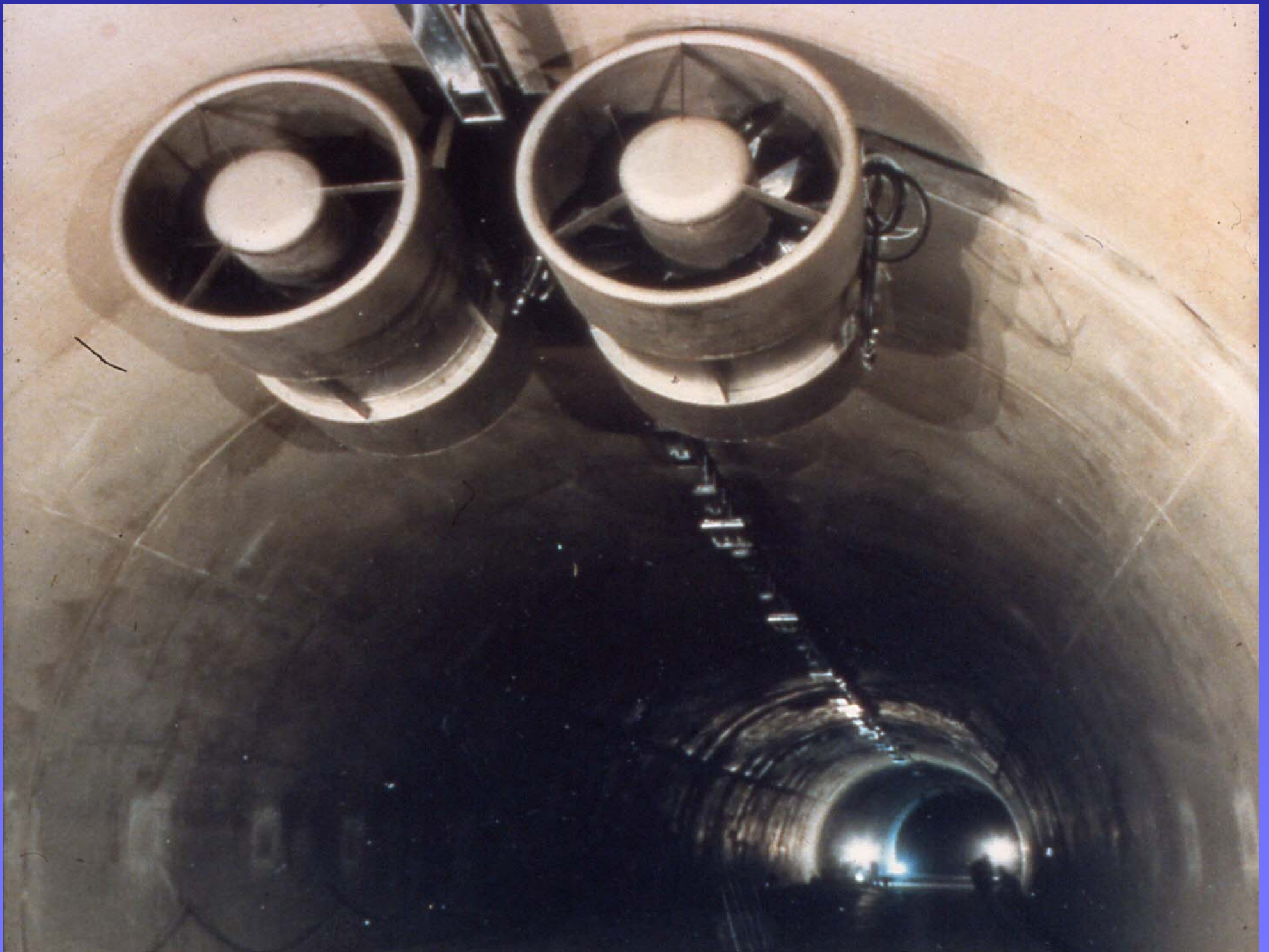




# All these efforts help

- to overcome public **discomfort** and **fears** using tunnels
- to ensure the politically high-profiled **mobility** in our modern societies







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**There is no doubt:  
In our daily life  
we need tunnels!**

**Let us build them!  
Let us make them safe!  
Let us use them!**







**Tunnels can be safe!**

**Tunnels must be safe!**

**Thank you very much  
for your kind attention!**