Brennerpass tunnel

Design – Construction - Safety
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15th Greek Conference on Concrete
Content

General Informations
  • Design Optimisation
  • Construction
  • Safety Aspects

Conclusions
Informations to the project
Base Tunnel

The length

Base Tunnel + Innsbruck Tunnel
55,000 km + 7,7 km = 62,758 km

longhest tunnel worldwide

In Austria: 38,445 km
In Italy: 24,313 km

Maximum speed: 250 km/h
Brenner-Base Tunnel

1. TEN-project
Berlin - Neapel
• appr. 22.000 m geological explorations
Design Optimisation
General view

Eisenbahn Bestandsstrecke
Umfahrung Innsbruck
Südzulauf
Autobahn Trasse 2002 mit Zufahrtstunnel und Zwischenangriffen
MFS 2002
Trasse 2005 mit Zufahrtstunnel und Zwischenangriffen
MFS 2005
Umfahrung Innsbruck
cross section

distance 40 - 70 m

cross passage
Cross section with exploration tunnel

- Main tunnel 1: 8.0 m
- Main tunnel 2: 8.0 m
- Exploration tunnel: 5.35 – 5.65 m
- Distance: 40 - 70.9 m
Cross section with exploration tunnel

Haupttunnel 1
Galleria principale 1

Haupttunnel 2
Galleria principale 2

Schleusentore
Porte ermetiche

Querschlag
Raccordo trasversale

Erkundungsstollen
Cunicoli esplorativi
Cross passage in a distance of 333 m
Multifunctional area (MFS)
Steinach am Brenner
Multifunctional areas (MFS)
Innsbruck & Pfitsch
Construction methods
Quaternary & tertiary soft rock
(weathered clay; oligocene clay)

Strongly weathered bedrock

Bedrock, moderately to strongly weathered
(sandstone/greywackes/quartzite; W3-W4)

CUT & COVER AREA
Compact Pipe Roof – Soil  d=139 mm
Mechanized excavation
Safety aspects
Reliability assessment – Risk Analysis

Cornell’s reliability index

\[ \beta = \frac{\mu_Z}{\sigma_Z} \]

\[ \mu_Z = \mu_R - \mu_E \]

\[ \sigma_Z^2 = \sigma_R^2 + \sigma_E^2 \]
Risk Analysis

The interventions realised by the Brenner Base Tunnel:

• Reducing the accidents probability
• Reducing fatalities
• Minimizing accidents consequences

The adopted scientific method is the RISK ANALYSIS
The **Fatal accident probability** $\Pi$ is given by the combination of the curves

**Safety features and Users Behaviour:**

- **D** Safety Features
- **U** Users Behaviour

![Diagram showing the combination of safety features and users behaviour with a fatal accident probability $\Pi$.]
The introduction of new safety features and systems leads to different effects on the curves D and U.
Safety Analysis

1. Detection: fire- and smoke detection, permanent CO, opacity and wind velocity measuring

2. Optical Signalling systems

3. Self rescue - test by fire brigades
   (Mobile Gas-Analysis Equipment)

4. Structure: tunnel shell, structural components, rails, etc.

5. Mitigation Systems
   Heat release: appr. 200 – 500 MW
Test procedure for "self rescue in tunnel fires". Simulating slow and fast escaping.

Group I $v = 0.8 \text{ m/sec}$

Group II $v = 0.4 \text{ m/sec}$
Analysis and results – walking phase
USER BEHAVIOR
Evacuation study and crowd videos

Response phase
- 18% leaves train, car spontaneously without announcement
- small group responds within a minute
- larger group starts after 2.5 minutes

Hesitation phase (wasting time around train, car)
- spontaneous action results in longer hesitation time
- 75% waited longer than 100s!!
Different heat releases: 10 MW, 20 MW, 30 MW
TIME – TEMPERATURE - CURVES

- Rijkswaterstaat-Curve
- Hydrocarbon-Curve
- ISO Standard-Curve
- RABT-Curve
the video alarm system is able to register the smoke after 15 sec

5 sec  15 sec  150 sec
white and green illuminated markers

• foot level

• eye level
Behaviour of railroad tracks under high temperatures

1. Railway - Concrete Temperatures
2. Railway - Bolt Temperatures
3. Railway - Steel Temperatures
4. Railway - Air Temperatures
Concrete spalling under fire

- Shot concrete plate
- Strap plate
- Drilling core; d=5 cm
- Spalling
- Side of Fire
- d=10 cm
- 2 cm
Failure modes

- Loss of bond strength
  - cause
    - Heating of the interaction zone

- Failure of the tensile zone
  - cause
    - Heating of the reinforcing bars

- Failure of the compression zone
  - cause
    - Decrease of the compressive strength

Concrete spalling
  - global
  - local
  - explosive

cause

- residual stress caused by different temperatures gradients
- Phys. + chem. Changes in the structure matrix
- Appearing tensile strengths by escape of vapour
Causes of thermal spalling phenomenon

High pressure of vapour

+ 

water from dehydration

moisture clog

Spall of concrete

Constraints for thermal dilatation

Mechanical stresses

stresses:
aggregate - cem. matrix
+ 
thermal degradation
+ 
chemical degradation
Innovative software FaHiCoVMaC works properly with 2Dfluid-2Dsolid and 3Dfluid-3Dsolid coupling and interfaced with a complete structural code.

**Results - tunnel cross section**

**Fluid**

**Concrete Vault**

Velocity vectors and temperature contour lines

Temperature contour lines
Thermal Analysis by using Inverse Method

Statistical methods (program FREET) and ATENA thermal analysis were used to determine thermal conductivity and capacitivity from experimental results.

Interface
Temperature < 300°C
Concrete Damage

remaining relative concrete strength as a function of time
Relativ compressive strength vs temperature
Mitigation systems – water supply

water containment ca. 100 m³ con sedimentatore
Ventilation in the cross passage

Dimensionamento:
- Distanza S > 1 m
- 2 Ventilatori 0.5 kW
- 1 Serranda 10 W

Rand des Seitenbanketts (1.97 m ab Gleisachse)
Querschlagabschluss
Querschlag

6 m

Bahntunnel
Belüftung-QS-Schema_Venti3.cdr
Evacuation concept
Externally of the emergency areas

Querschlag (Fluchtweg)

Evakuierungszug

Unfallzug

Tunnel West
Richtung Innsbruck

ca. 30-50 m

Tunnel Ost
Richtung Franzensfeste

ca. 336 m

Externally of the emergency areas
Evacuation concept from the emergency areas

- Nothaltestelle Ost
- Verbindungsstollen
- Evakuierungszug
- Tunnel Ost
  Richtung Franzensfeste
- Tunnel West
  Richtung Innsbruck
- Unfallzug
- Seitenstollen (Fluchtweg)
- Zugangsstollen (Fluchtweg)
- Nothaltestelle West
# Conclusions

The longest railway tunnel in the world

First project on the TEN - list

<table>
<thead>
<tr>
<th>Exploration tunnel:</th>
<th>2007</th>
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<tbody>
<tr>
<td>Construction of the base tunnel</td>
<td>next 15 year</td>
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<td>400 trains / day</td>
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<tr>
<th>Total cost</th>
<th>appr. 5.000 mio Euro</th>
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<tr>
<td>Construction cost</td>
<td>appr. 3.500 mio Euro</td>
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<tr>
<td>Cost relating to safety</td>
<td>approx. 800 mio Euro</td>
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Thank you!

Vigilius - „The watchful or vigilant“. 

St. Vigilius
Ca. 360 - 405