Gotthard Basetunnel
Aspects of Long Tunnels

presented by:
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3. Gotthard Basetunnel: Some Constructional Aspects

4. Risk and Risk Mitigation

5. FCC and Gotthard Basetunnel
Introduction

Main Challenges of Long (and Deep) Tunnels

- **Tunnel length leads to long construction time**
  - Mechanization / automation of procedures, trend to the use of TBM in order to increase performance
  - Intermediate points of attack (if feasible) to cut construction time

- **Geological variety, (high overburden)**

- **Investigations**
  - Not possible / reasonable over the entire length
  - Higher remaining risks compared to other projects

- **Logistics**
  - Long transport distances
  - Access shafts and galleries

- **Muck treatment, material deposits**
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More and More People and Goods Cross the Alps

(Source: GBT, der längste Tunnel der Welt, Die Zukunft beginnt, Hrsg. R.E. Jeker Werd Verlag Zürich, 2002)
Traffic Crossing the Alps, Estimated Increase between 1991 and 2020

### Passengers

<table>
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<th>Year</th>
<th>Million passenger trips/year</th>
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<tr>
<td>1990</td>
<td>65</td>
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<td>2020</td>
<td>100</td>
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- Traffic through the Alps via Mt. d'Ambin/Fréjus and Brenner (rail + road)
- Proportion Gotthard railway

### Freight

<table>
<thead>
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<th>Year</th>
<th>Million tonnes/year</th>
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<tbody>
<tr>
<td>1990</td>
<td>70</td>
</tr>
<tr>
<td>2020</td>
<td>140</td>
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</tbody>
</table>

- Traffic through the Alps via Mt. d'Ambin/Fréjus and Brenner (rail + road)
- Proportion Gotthard railway

(Source: www.alptransit.ch)
The Modernisation of the Railway Infrastructure Shall Enhance Transferring Traffic from Road to Rail

The political pressure from the EU to have more traffic capacity through the Alps resulted in a political decision in Switzerland that this traffic should be on rails

(Source: www.alptransit.ch)
What’s the Gotthard Axis?

The Gotthard axis includes the:
- Zimmerberg Base Tunnel (works are suspended)
- Gotthard Base Tunnel GBT (under construction)
- Ceneri Base Tunnel (under construction)

The new route makes freight transportation more productive and passenger traffic faster

(Source: www.alptransit.ch)
Gotthard Axis, Longitudinal Profile

- Existing Zimmerberg Railway Tunnel
- Existing Gotthard Railway Tunnel
- Existing Ceneri Railway Tunnel

Locations:
- Gotthard-Basistunnel
- Ceneri-Basistunnel
- Zimmerberg-Basistunnel
- Arth-Goldau
- Altdorf
- Goeschenen
- Airolo
- Biasca
- Lugano
- Chiasso
- Milan
- Bellinzona
- Zug
- Zurich
- Basel
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Reasons of the Swiss Government for the NEAT

- **Transport political**: transfer long distance traffic from road to rail
- **Environmental**: reduction the number of trucks, protection of the environment
- **National politics**: network instead of only one axis, improved connection between north and south
- **Economical**: connection to Europe‘s high speed rail network
- **European political**: Switzerland strengthens its central role in Europe
Public Votations on the NEAT Project

For the NEAT scheme the Swiss population voted three times:

- on the introducing of a tax on the transportation of heavy goods (freight)
- on the overall financing of the project
- on the technical scheme: network instead of only one axis
Over-all Organisation: Federal Government, Operating Companies and Clients

Federal Council
Parliament
Departments

Operating companies
SBB
BLS

Clients
BLS AT
ATG
RhB
MGB
SOB
SBB
BLS
SBB

Lötschberg
Gotthard Ceneri Zimmerberg
Surselva
St-Gallen – Arth-Goldau
Ausbauten übriges Netz und Hirzel

(Source: www.alptransit.ch)
**Planning Approvals Procedure**

- publications in official journals
- 30 days for public consultancy at the local communities
- public stake out

**Authorised to raise objections**
- Owners of affected estates
- Keepers of respective rights as neighbours
- Person who are concerned as leasers or tenants
- Communities

**Where to raise objections**: only directly at the BAV (Ministry of Transport)
Permanent Communication: Bodio Visitor Centre
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Source of the Capital (30 Billion CHF – for entire NEAT scheme)

- Oil tax approx. 25%
- Value added tax approx. 10%
- Heavy goods vehicles tax approx. 65%

(Source: www.alptransit.ch)
Use of the Capital (30 Billion CHF)

- Rail 2000 1. Phase ca. 25 %
- Rail 2000 2. Phase ca. 20 %
- Zimmerberg Base Tunnel ca. 3 %
- Gotthard Base Tunnel ca. 20 %
- Ceneri Base Tunnel ca. 5 %
- Lötschberg Base Tunnel ca. 10 %
- Reserves ca. 7 %
- Noise reduction (incl. rolling stock) ca. 5 %
- Connection to the European high speed network ca. 5 %

(Source: www.alptransit.ch)
Credit versus Contract Costs

The NEAT credit:
- was established at a very early phase and was approved by the government
- it was based on a ‘probable’ geological situation and has a reserve lump sum for ‘unexpected events and conditions’

The NEAT costs:
- the cost is the sum of all contracted works
- the cost forecast is constantly (i.e. every 6 months) up-dated according to the progress of the planning and/or the work and compared with the credit.

The margin between costs and credit was originally + 25%. The final costs can now be estimated with +/-5%.
Development of Total Costs and Risk Potential (total axis)

- Estimated total costs: 11'836
- Estimated total costs: 11'874
- Estimated total costs: 11'800
- Estimated total costs: 11'878

Risk potential

(Source: AlpTransit Gotthard AG)
Cost Overruns: Magnitude and Reasons

There had been a constant increase in investments and costs for the Gotthard Basetunnel (primarily figures)

Magnitude in total: approx > 3 Mia CHF (ca 40%)

Reasons:

- Contracts and construction: approx 2%
- Geology: approx 18%
- Improvements for the public and the environment: approx 7%
- Political delays and financial restrictions: approx 21%
- Safety and state-of-the-art technology: approx 53%

Quelle: AlpTransit Gotthard AG
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Three Alternatives for the Alignment of the GBT

Selected alternative

49.2 + 7.8 = 57 km
the Northern portal was shifted from Amsteg to Erstfeld

(Source: GBT, der längste Tunnel der Welt, Die Zukunft beginnt, Hrsg. R.E. Jeker Werd Verlag Zürich, 2002)
Geological Alignment

- Areas with highest overburden ➔ bypass
- Major fault zones:
  - „Tavetsch Intermediate Massif“ ➔ shortest possible crossing
  - „Useren Gavera Zone“ (probably aquiferous) ➔ drive on the rise
  - „Piora Basin“ ➔ shortest possible crossing, upwards drive
- As large distant to reservoirs and dams possible
Overview GBT

Gotthard-Basistunnel
length 57 km

Erstfeld
length 7.4 km

Amsteg
length 11.4 km

Sedrun
length 6.8 km

Faido
length 14.6 km

Bodio
length 16.6 km

AlpTransit Gotthard
open line
presented
postponed
existing railway line
shaft, adit
exploratory drills
Pitasycline
Possible Tunnel Systems of the GBT

1 double-track tunnel and 1 service tunnel

2 single-track tunnels and 1 service tunnel

3 single-track tunnels, of which one used as service tunnel

2 single-track tunnels constructed to higher standard

- Blue: Φ = 12.3 m
- Yellow: Φ = 7 m
- Red: Φ = 9.2 m
Standard Cross Section TBM Drive

- Tolerance
- Space for deformation
- Preliminary rock support
- Main drainage
- Cross section: 66.48m²
- Waterproof membrane
- Clearance profile
- In situ concrete lining
- Secondary drainage
- Concrete trackway

Cross section: 66.48m²

R = 3.95 m
9.30 m

Gotthard Base Tunnel, Schedule


(Source: www.alptransit.ch)
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Gotthard Base Tunnel, Geological Longitudinal Profile

Two major geotechnical critical zones
Geological Investigations TZM and UGZ
Exploration Drillings during Excavation
3D Tunnel Seismic Prediction ahead of Tunnel Face

- 1 or more shot lines w/ small explosive charges
- 4 receivers
3D Tunnel Seismic Prediction

3D-seismic velocity distribution ahead of the tunnel face
3D Tunnel Seismic Prediction

3D also, under specific conditions, of karst phenomena

Exploration - Decision Tree

Vorauserkundung TBM-Vortrieb

Konzep

Ausführung

Bereit: R175/05.510 J
Amberg Engineering AG, Regensdorf, 22. Mai 2008

Abbildung 2: Ablaufschema für die Vorauserkundung
**Systematic exploration**
- Measure of temperature
- Tunnel Seismic Prediction
- Percussion drillings
- Protected with preventer

**Depending on the results**

**Additional exploration**
- Borlog scanning
- additional percussion drilling
- Core drilling
- Protected with preventer
Preparation for all site characteristics
Logistics – Important Support

Question of priorities between
- costs and
- time
limited by feasibility
- economical and
- technical
The combination of 2 TBM (instead of 4) for the excavated lots means:
- the concreting of the lining in parallel to the excavation due to construction time constraints
- a high performance transport system on tracks and not with conveyors
Logistics

- Logistics is the responsibility of the ‘production’
- Highly skilled staff needed
- Professionnel behaviour needed
- High flexibility needed
- «Trouble shooting» is base requirement
- Information flow is vital
Logistics through Shafts

Definition of a coherent logistic concept serving as base for:

- the necessary hoisting systems in the shaft
- all other elements of the supply chain
- final necessary shaft diameter
- necessary transport handling elements at the shaft foot
Base for the Shaft Dimensions

Construction period
- Hoisting of muck material
- Supply of support material
- Transport of all further material
- Ventilation (fresh air and exhaust air)
- Hoisting of personnel and rescue
- Supply pipelines

Operation period
- Exhaust air shaft
- Fresh air shaft
- Space for hoisting installations
- Cable ducts
Logistics through Shafts
Sedrun Shaft at Gotthard Base Tunnel

Portal installation field
Access tunnel
Concrete plant, silos
Depth ~800 m
Counterweight
Pipeline for pneumatic cement conveying
Trackbound transport
Cage for:
- carrying persons
- excavated material
- construction material
Ventilation tunnel
Gotthard Base Tunnel

Northern drives
Foot of shaft
Trackbound transport
Southern drives

Main Characteristics of Sedrun Shaft

- 800 m deep
- Diameter of excavation 8.6 m
- Preliminary support with shotcrete and anchors
- Concrete lining $t = 25$ cm
- Inner diameter 7.9 m
Construction Phases (Excavate the Caverns at Shaft Foot)
Caverns at Shaft Foot
Bench Heading in Longitudinal Cavern
Concrete Production Plant at Shaft Foot

Even large end complex installations can be put at the foot of shafts and run from there
Assembly of TBM Underground
TBM + Back-up Installations = 440 m

TBM can be assembled, transported from one drive to the next and disassembled underground

Source: www.AlpTransit Gotthard.ch
TBM Transport Underground by Low-Loading Truck
Dismantling of TBM Underground

(Source: www.Apltransit.ch)
Dismantling of TBM Underground

Source: AlpTransit Gotthard AG
TBM in soil and water pressure up to 10 bars are state of the art (example: Westershelde Tunnel in NL)
Nowadays rock and soil can be excavated with the same TBM, necessary adaptations are made underground (example: Weinberg tunnel Zurich)
Final Lining

TBM and segmental lining with pre-casted elements results in a watertight final lining
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Amounts of Excavated Material

(Source: GBT, der längste Tunnel der Welt, Die Zukunft beginnt, Hrsg. R.E. Jeker Werd Verlag Zürich, 2002)
Recycling of Excavated Material

- Concrete aggregate: 22%
- Filling material Recultivation: 24%
- Inert landfill: 1%
- Construction materials: 4%
- Filling material for cultivation: 49%
- Recycling by third parties
Muck Treatment Plant on Installation Site Amsteg

(Source: www.Apltransit.ch)
Faido - Muck Treatment / Concrete Production

Quelle: AlpTransit Gotthard AG
Muck Conveyor Belt
Faido - Muck Deposit Caviencia

Quelle: AlpTransit Gotthard AG

Bodio – Muck Deposit Buzza di Biasca
Sedrun - Muck Deposit Val Bugwei

Quelle: AlpTransit Gotthard AG
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5. **FCC and Gotthard Basetunnel**
Gotthard Base Tunnel, Tunnel System and Emergency Station
Design and Risk Assessment Process

Safety integrated design for the GBT

AlpTransit Gotthard Ltd

Risk Analysis
Safety measures
Safety concept
Safety documentation

Authorities
Risk Analysis
Safety measures
Safety requirements
Safety report, recommendations

Best solution = Maximum Total Utility

Aim at the overall best solution:
- Include various aspects (in accordance with the defined objectives and goals)
- Define total utility by weighing of the relevant aspects:

```
Construction costs
Operation costs
Maintenance costs
Demolition costs
Environmental related costs
Traffic related costs
Hazard effects
```

Life cycle costs

Total economic life cycle costs

Construction    Operation    Safety
Comparison of Solutions

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<th>Variant A</th>
<th>Variant B</th>
<th>Variant C</th>
<th>Variant D</th>
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<td>0.2</td>
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<td>0.5</td>
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<tr>
<td>Operation</td>
<td>0.4</td>
<td>0.333</td>
<td>0.25</td>
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<tr>
<td>Safety</td>
<td>0.4</td>
<td>0.333</td>
<td>0.25</td>
<td>0.15</td>
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</table>
Risk and Safety Assessment

- Stepwise approach adapted to the actual needs
- Hazard identification / analysis
- Safety Review / benchmarking
- Qualitative risk analyses
- Quantitative risk analyses
- Supporting technical investigations and tests (specification of / use of)
Other Tunnel Types than Railway Tunnels

The integrated design process is dependent on the actual conditions of
- the tunnel
- the traffic and composition
- economy
- Safety and rescue concepts
- operational conditions
- etc.

For another tunnel even of similar length some significant parameters may deviate.
Hereby another concept for the tunnel may prove to be preferable.
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</table>
Risk Management in Underground Construction

In the Gotthard Axis the constructional risks and their cost relevance have been evaluated at least every 6 months.
Risk Management

Risk management is the systematic process of identifying, analyzing and responding to project risks.

Risk management is
- not only a single event
- a continuous process during the entire project.

Therefore the risk control is part of the project life cycle from project initiation to project completion.
Risk Responding, Range of Geological Risks 1992 and Accuracy of Cost Estimation +/- 25%

(Source: Baumgärtner, Büchler, Systematik der Kostenrisiken am Beispiel Gotthard Basistunnel, Kasseler Projektmanagement Symposium 2005)
Risk Responding, Range of Geological Risks 2002 and Accuracy of Cost Estimation +/- 10%

(Source: Baumgärtner, Büchler, Systematik der Kostenrisiken am Beispiel Gotthard Basistunnel, Kasseler Projektmanagement Symposium 2005)
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## FCC and Gotthard Basetunnel

### Purpose
- **GBT**: Single track high speed train tunnel
- **FCC**: Experimental structure
- **C**: Comparable, **nc**: Not comparable

### Rock Conditions
- **GBT**: Pre alpine and alpine rock formations heavily tectonically deformed with great fault zones (expl. Piora)
- **FCC**: Mostly flat layers of bedrock few disturbed in contact zones with pre alpine rock and limestone of Jura formations

### Overburden
- **GBT**: Up to 2000 m middle hard to hard rock often tectonically deformed metamorphic rock
- **FCC**: Up to 600 m soft to middle hard rock mostly undisturbed bedrock

### Core Drilling (Geol. Prospection)
- **GBT**: In the high mountains often impossible to find access or place to drill systematically every some 100 m
- **FCC**: In FCC area every point of the future construction can be easily reached with a core drill

### Tunnel Temperature
- **GBT**: Rock temperature span lies between some minus degrees (winter time) up to over 40 degrees
- **FCC**: More or less constant rock temperature, variations of temperature might influence experiments

### Air Movements
- **GBT**: High speed trains are pushing the air through the tunnel when passing
- **FCC**: No air movements except turbulences in areas where a machine is producing a lot of heat

### Fresh Air
- **GBT**: During operation air has to be changed continuously also to avoid upcoming mist which affects train drivers sight
- **FCC**: During maintenance FCC to be ventilated according to number of staff and machines in tunnel, for operation specifications are to be fixed

### Fire-Life-Safety-System
- **GBT**: Persons in trains are not trained to behave during any hazard or how to extinguish a fire
- **FCC**: Staff of CERN will be trained and well instructed about where to go or handle any hazard

### Evacuation
- **GBT**: Up to 1000 persons in one train have to be brought as fast as possible to a safe well illuminated and ventilated protected room or through an escape tunnel to the surface
- **FCC**: Staff in sectors which can be evacuated can use this way, all others can be brought to safety chambers (also used during construction and accelerator installation) to wait there for being rescued

(c = comparable, nc = not comparable)
### FCC and Gotthard Basetunnel

<table>
<thead>
<tr>
<th>Item</th>
<th>GBT</th>
<th>FCC</th>
<th>c</th>
<th>nc</th>
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<tbody>
<tr>
<td>Realization of FCC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>owners organisation (planning/ realization/ starting operation)</td>
<td>complex project with different stages (planning construction, rail engineering and safety/ tendering and realization civil construction / tendering and realization rail engineering / tendering and realization rail engineering / tendering and realization safety / hand over from construction to rail engineering and safety installations, starting operation)</td>
<td>complex project with different stages (planning construction, accelerator and safety / tendering and realization civil construction / tendering and realization rail engineering / tendering and realization accelerator / tendering and realization safety / hand over from construction to accelerator and safety installations, starting operation)</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>site logistic</td>
<td>5 big building sites were necessary to realize the whole project, sites also used for rail engineering and safety purposes</td>
<td>4 – 5 big building sites and 4 to 5 middle sized building sites will be necessary to realize the whole project, sites also used for accelerator installation and safety purposes</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>aggregate processing of muck and/or disposal</td>
<td>all building sites were equipped with aggregate processing plants to prepare aggregates for the concrete, muck was disposed in landfills and lake Lucerne</td>
<td>Encountered rock is mostly not suited for aggregate processing, muck could be used for landscaping around surface buildings of shaft accesses, rest to be deposed in landfills</td>
<td>x</td>
<td>(x)</td>
</tr>
</tbody>
</table>

(c = comparable, nc = not comparable)
Thank you very much for your kind attention!