GOTTHARD BASE TUNNEL (GBT)

AlpTransit, Gotthard Base Tunnel, Switzerland

The route over the Gotthard is part of the international north-south alpine transversal. The base tunnel with a length of 57 km and an overlying rock mass of up to 2‘300 m is one of the longest railway tunnels in the world enabling a train speed of V_{max} of 250 km/h.

Scope

- 2 parallel single track tunnels with a diameter of 9 – 13 m and a length of 57 km each, from Erstfeld to Bodio. In total with all access tunnels cross-passages (at 312 m intervals) & shafts the lengths of sub terrain constructions adds to 157 km.
- 2 multifunction stations (MFS) at Sedrun and Faido.
- Subdivision of the entire stretch of 57 km in 5 sections with 3 intermediate headings:
  - Erstfeld 7.7 km
  - Amsteg 11.3 km
  - Sedrun 8.6 km incl. MFS
  - Faido 13.4 km incl. MFS
  - Bodio 16.0 km

Challenges

- Alpine Geology, massive tectonic fault zones
- Overburden up to 2‘300 m, ductile reinforcement & lining coping with radial deformations of up to 0.8 m
- High formation temperatures of up to 44°C
- Long duration of the project, complex logistics
- Extreme requirements on quality & sustainability

Amberg Services (Sedrun / Faido / Bodio)

- All phases of the project from detailed project, building project, submission, and implementation project up to complete construction documentation and site supervision
- Stability analysis and proof, geotechnical construction support, risk analysis
- Test and commissioning of operational and safety installations in the entire tunnel

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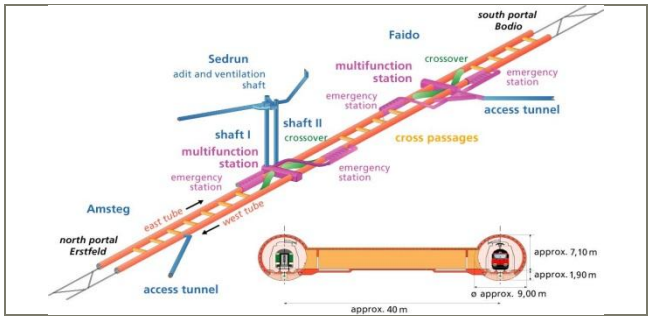
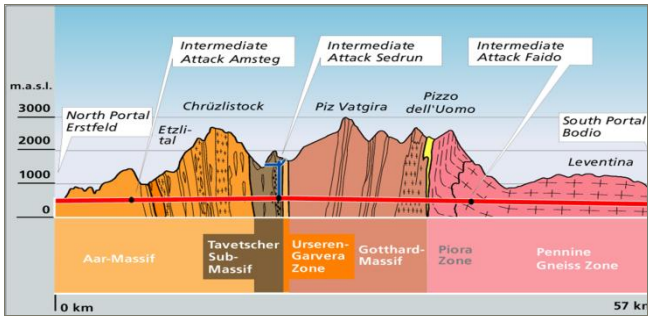


- Layout Gotthard Base Tunnel



- Simplified geology

- Rock burst at the multifunction station Faido

AMBERG FACTS

Contracted value JV

- JV with Pöyry Infra AG and Lombardi SA Ingegneri Consulenti under lead of Amberg Engineering AG: Total approx. 485 Mio CHF

Contracted value Amberg

- Total approx. 165 Mio CHF

Projectphases & duration

- Start Planning 1990
- Construction 1993 – 2016

Project details

Section Sedrun incl. multifunction station (MFS)

- Access gallery 1 km length, cross-section 38 m^2
- 2 vertical shafts, depth approx. 800 m, diameter 8.6 m resp. 7.0 m
- Inclined ventilation shaft, length 255 m, 14 m^2
- Multifunction station with emergency stops of 1.7 km lengths on the level of the single track tunnels
- 2 single track tunnels of 6.9 km length each, cross-section 60 – 135 m^2
- Drill & blast heading for tunnels and MFS

Section Faido incl. multifunction station (MFS)

- Access gallery 2.6 km length, slope 12.7 %, 63 m^2
- Multifunction station with emergency stops on the level of the single track tunnel, length 2.3 km, maximum excavation area 328 m^2 (branch off)
- 2 single track tunnels, 11.1 km each, 70 m^2
- TBM heading for tunnels, drill & blast for MFS.

Section Bodio

- 2 single track tunnels, 16.0 km each, 63 m^2, thereof soft ground / open cast section of approx. 800 m.
- For rock section: TBM heading, partially drill & blast, pipe umbrella in soft ground section (105 m^2)

CLIENT FACTS

Overall cost

- Total approx. 12.2 bn CHF

Overview project

- 2 parallel single track tunnel with diameter of 9 – 13 m and 57 km length each, from Erstfeld to Bodio
- The 57 km long stretch is subdivided in 5 sections: Erstfeld, Amsteg, Sedrun incl. MFS, Faido incl. MFS and Bodio
- Heading from both portals and 3 intermediate accesses at Amsteg, Sedrun und Faido

Geology

- Mainly crystalline rock mass, the crystalline massifs are separated by tectonic zones with sedimentary insertions.
- The 3 crystalline massifs include the Aare massif in the north, the Gotthard massif and the penninic gneiss zone in the south
- Main hazards are the rock bursts, caused by the high stresses of the overlying rock mass and the instabilities of chunks of rock with poor quality, together with water ingress under extreme pressure.

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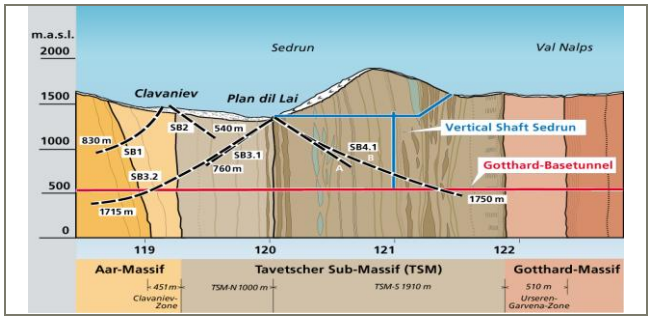
CHALLENGES SEDRUN

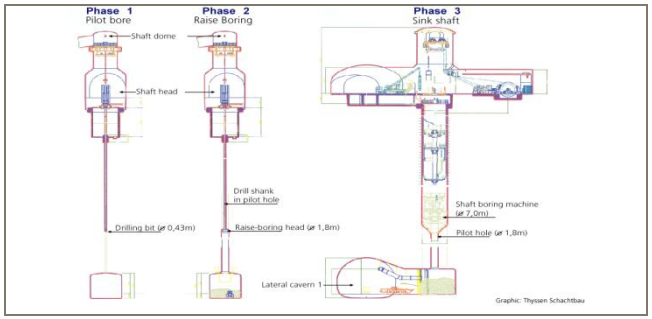


- Geologic profile of the section Sedrun

Difficult Geology and Logistics

- The section Sedrun was the most demanding part of the entire GBT in relation to logistics and control of the extreme mountain conditions.
- As a consequence of the complex geological conditions, a comprehensive investigation program from surface was conducted, comprising boreholes of up to 1‘750 m length.
- In addition the entire heading in this area was accompanied by pre-investigations.
- The drill rigs needed to be equipped with blow out preventers, to avoid water- resp. mud / sand-ingresses with high hydraulic pressures of up to 200 bars.
- In the Tavetscher Zwischenmassiv Nord, north of the nowadays MFS, the geology with kakirite gneisses and schists was extremely difficult (squeezing rock).

ENGINEERING APPROACH SEDRUN



- Sinking of shafts from the access gallery

Access Gallery and Vertical Shafts

- The access gallery (1 km), the inclined ventilation shaft (255 m) and the cavern above the vertical access shafts (each 800 m) were built in preparatory construction lots.
- Shaft 1 with a diameter of 8.6 m was excavated by drill & blast from the shaft head cavern at the level of the access gallery.
- Shaft 2 was built later in 3 phases:
  - In a first phase a pilot borehole with a diameter of 43 cm was drilled.
  - In a second phase this borehole was extended by a raise drill hole to a diameter of.
  - In a third phase the shaft was widened to its final diameter of 7m using a Topdown-TBM.

TECHNICAL SOLUTIONS SEDRUN

- MFS Sedrun, tunnel branch off

Tunnel Headings in the Sedrun MFS

- The entire logistic for the heading of 2 x 8.6 km tunnel and the MFS (4 simultaneous headings plus excavation of the MFS cavern) needed to be served by both shafts and the access gallery disposal and provisioning. The twofold broken transport chain required a thorough planning of logistics.
- More than 6‘000 tons of excavation material needed to be transported every day. In total 5.46 Mio tons of excavation material and provisioning of 1.41 Mio tons of aggregates were mastered.
  The shaft hoisting system with conveyor cage had a payload of 50.8 tons and a power of 4.2 MW, enabling a max. conveyor speed of 18 m/s.
- The squeezing rock conditions of the Tavetscher Zwischenmassiv could be anytime well controlled with a tailored supporting system (flexible steel support). With a full section excavation each day 1 m tunnelling progress could be accomplished.

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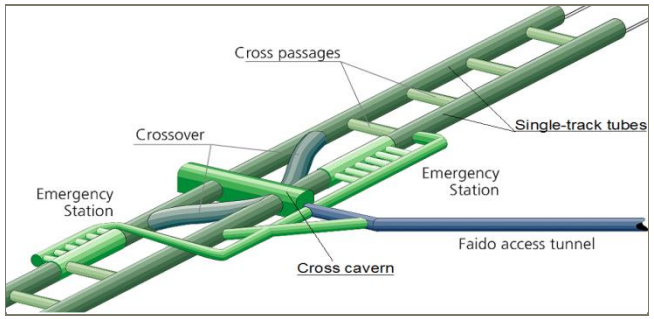
CHALLENGES FAIDO

- Rock burst / restoration with steel reinforcement

Rock Bursts / Instabilities at Fault Zones

- The problems in relation to the substantial deformations (> 1 m radial deformation) in the vicinity of a bigger fault zone could be mastered with by means of massive anchoring (up to 975 m of anchors per meter tunnel) and a flexible tunnel reinforcement, as well as the stabilisation of areas with rock bursts.
- Rock bursts were observed in several heading sections because of the high overburden (average 1'500 m). These rock bursts induced micro-earthquakes with a strength of 2.4 (Richter scale), which among others could be registered by the Swiss Earthquake Survey in the region of Faido.
- Despite of the immense difficulties of the excavation of the MFS Faido one succeeded to prepare the MFS in such a way, that both TBM's from direction of Bodio could make the breakthrough in due time. The TBM's were partially disassembled and moved through the MFS in such a way, that they could start the heading in the direction of Sedrun.

ENGINEERING APPROACH FAIDO

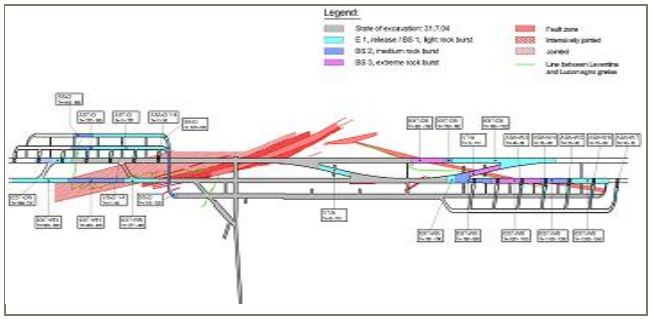


- Scheme of the Faido MFS (planned layout)

MFS Faido as Planned

- The MFS Faido is located at the end of the access gallery Faido, which has a length of 2.3 km.
- The MFS consists of 2 emergency stops, which are connected by an overpass. In case of an event people can use the escape routes to be evacuated through the other parallel tunnel tube.
- The escape galleries are pressurized by an independent feed of fresh air, the smokes are exhausted with a separate ventilation system at the ventilation central at the portal of the access gallery. These systems provide the utmost safety fort rain passengers in terms of security.
- The 2 intersections (branch off's) between the tunnels serve e.g. in case of maintenance for the passage into the operating tunnel tube.
- The transverse cavern as well as other caverns also serve for housing of the railway infrastructure.

TECHNICAL SOLUTIONS FAIDO



- Adjusted layout of MFS as a result of the Fault zone (red)

MFS Faido, Adaptation to Geology

- In the area of the MFS a fault zone was tangentially intersected unexpectedly.
- A comprehensive investigation (drilling and seismic) enabled to determine the optimal layout for the MFS.
- Based on the result of the investigations the planning of the MFS could be adapted in such a way, that the bigger caverns, the branch off with cross-sections of up to 328 m^2 including the emergency stops could be located in rock of better quality in the southern area of the fault zone.
- The situation with the poor rock quality at the fault zone forced the engineers to a complete re-design of the MFS Faido during the construction works. This was a big, if not the biggest challenge of the tunnel for the project engineers and the site supervision.
- In order to meet the schedule, the contractor was busy at 7 points of attack at the same time.

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CHALLENGES BODIO

- Heading of section Bodio

Section Bodio with Variable Geology

- Approximately 200 m after TBM start, an unexpectedly flat lying fault zone was intersected, accompanied with loose to friable rock on a length of several hundred meters. This caused rock fall and voids of up to 6 m height above tunnel ceiling.
- Towards the end of the heading in the transition of the Leventina to the Lucomagno gneisses deformations of up 0.3 m caused a jamming of the TBM and a later extension of the profile on a length of almost 1 km.
- The average heading which could have been achieved was 9.6 m per workday for the western tube and 10.4 m per workday for the eastern tube.
- In addition 51 cross passages could be excavated and lined.

ENGINEERING APPROACH BODIO

- Heading and sealing of lining

Multiple Site Concept at Bodio Section

- The excavation of the combined lot Bodio-Faido were stretching over a distance of of up up to 30 km, which caused enormous logistic demands.
- The excavation and the lining including the sealing needed to be carried out at the same time. This required the project to be shaped in such a manner, that the construction works could be managed with a 2 track operation.
- In addition to the 2 TBM headings and the lining works the cross-passages were excavated and lined.
- The long transport distances led to special requirements for the concrete technology (long open time of the fresh concrete).

TECHNICAL SOLUTIONS BODIO

- Portal south at Bodio

Portal South at Bodio

- A diversion gallery with a length of 1’200 m was driven by D&B to circumvent the soil section in the portal area. Herewith a timewise unbundling could be achieved. Both TBM headings started northwards in an installation cavern at the end of the diversion gallery.
- By means of a 3.2 km long gravel haul gallery (TBM diam. 5.0 m) and a 3.7 km long conveyor belt more than 10 Mio tons of mucking material were transported to a deposit of the adjacent Blenio valley.
- The excavation in the 400 m long soft soil area of Bodio with massif landslide deposits (blocks with the size of a house) was conducted with umbrella pipe excavation plus injections in partial headings of calotte / stross.
- An average performance of 0.7 m per workday could be achieved.
- Ahead of the soft soil section, a 380 m long cut and cover section is located.

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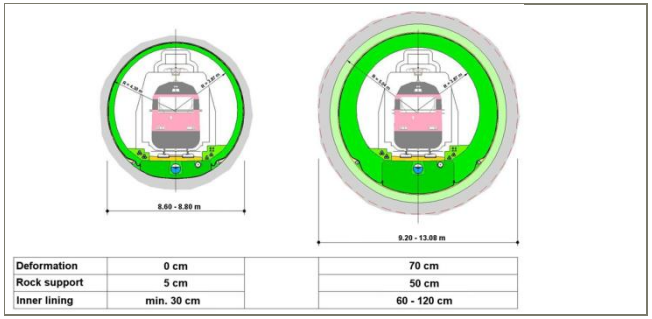
SECTION SEDRUN

- Rock reinforcement, fault zone using steel arches

- Site installation in the section Sedrun



Deformation	0 cm		70 cm
Rock support	5 cm		50 cm
Inner lining	min. 30 cm		60 - 120 cm

- Typical lining cross-sections

FAIDO MULTIFUNCTION STATION (MFS)

- Difficult formation at MFS Faido

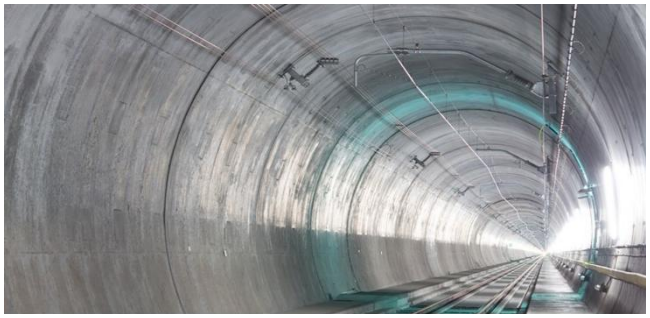
- Completion of excavation at MFS Faido

- Completed tunnel shell

SECTION FAIDO-BODIO

- Mucking in the area of the south portal

- Ventilation central at Faido



- Tunnel after commissioning

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FIRST PASSAGE

- View of the opening ceremony at Erstfeld

- First official passage with important state guests

- Panel discussion with some protagonists

OPENING SPEECHES

- Speech of Federal Council, Mrs. Doris Leuthard

- View of locomotive driving position 1st passage

- Applause for the engineers Gruber and Sala

OPENING FESTIVITIES

- Owner and representatives from Federal Council

- Engineers from Amberg enjoying the 1st passage

- Engineers in discussion with Mrs. Leuthard

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AMBERG TEAM @ WORK

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