

Construction of Uetliberg Tunnel

A. General Project Description

1. General

1.1. Project participants

Overall project and construction management:

Canton of Zurich Engineering Department

Project design and supervision:

Tunnelling and overall coordination:

Amberg Engineering Ltd., Regensdorf (Tunnelling and overall coordination)

Portal stations:

Fietz AG, civil engineers, Zurich (Wannenboden excavation and portal station)

Henauer + Gugler AG, engineering company, Zurich (Reppisch valley excavation and ventilation station)

Hans Eichenberger AG, engineers, Zurich (Gänziloo excavation and portal station)

Tunnelling contractors:

Uetli joint venture, c/o Zschokke Locher, Zurich; Murer AG, Erstfeld; Prader AG, Tunnelling, Zurich; CSC Bauunternehmung AG, Construction, Zurich; Wayss & Freytag, Munich/Frankfurt; Alpine Mayreder Bau GmbH, Salzburg-Wals; Spaltenstein Hoch + Tiefbau AG, Zurich

2. Geographical summary

The building of the N4/N20 Zurich western bypass is of great national and international importance in linking the Gotthard motorway with the A1 and A11. The routing of the 11 km long Zurich western bypass includes sections of open road and a number of tunnels, of which the Uetliberg tunnel is the longest at 4.4 km. The ambitious target of creating an environmentally friendly, rapid and convenient transport link to divert through traffic travelling east-west away from the city of Zurich is now being achieved with the construction of this bypass (see Fig. 1). Traffic forecasts indicate vehicle numbers of 70,000 in both directions by 2010.

The Uetliberg tunnel links the Birmensdorf bypass (N20.1.4) in the west with the existing Zurich-Chur highway (N3) in the east. A substantial gap in the Swiss national road network can now be closed.

The actual planning and design of the Zurich western bypass began more than 30 years ago. After various route alterations and other project changes as a result of objections which went as far as the Federal Court, the actual project work and initial construction began in 1995. The preliminary construction work for the Uetliberg tunnel has been proceeding since 1998 and consists of all the necessary feeder infrastructure and other parts of the western bypass (total of 10.6 km of motorway, including 8.4 km of tunnel).

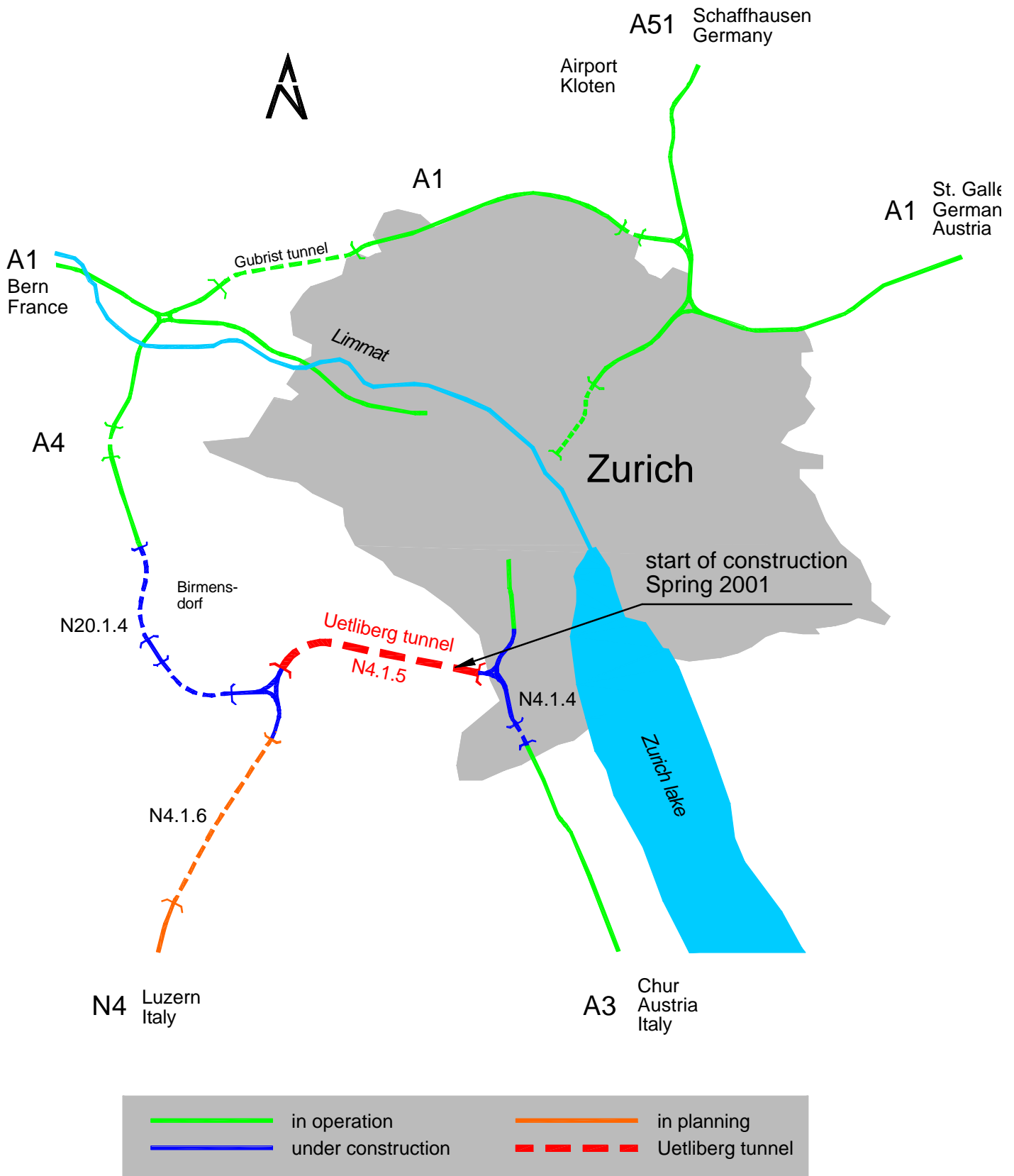


Fig. 1: Overview of Zurich western bypass

3. Uetliberg tunnel project components

The Uetliberg tunnel consists of two parallel tubes, each 4.4 km long, which rise about 1.6% between the Zurich South (Brunau) and Zurich West (Filderen) interchanges. The two tunnel tubes cut through the Uetliberg and Ettenberg hills. Between these two hills in the Reppisch valley is the 'Reppisch valley ventilation station' in the form of a cut-and-cover excavation about 230 m long.

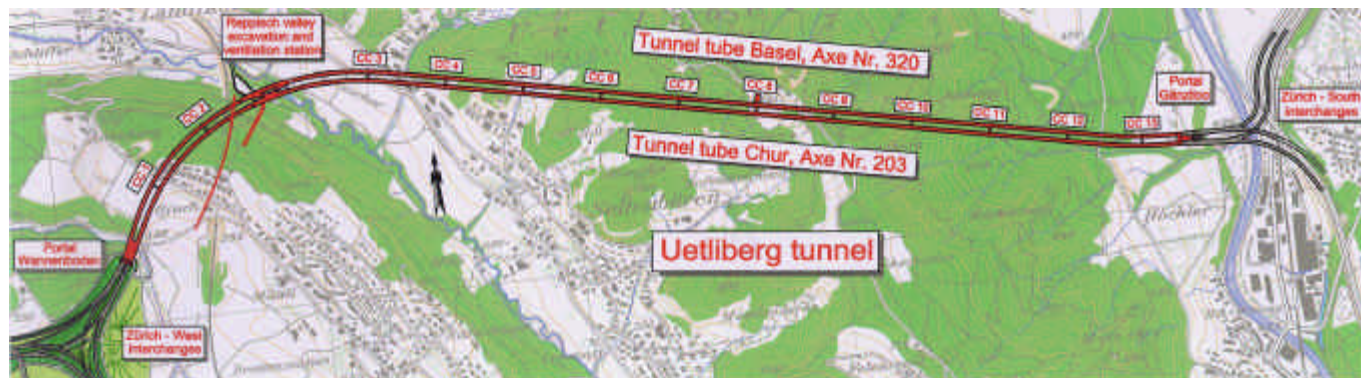


Fig. 2: Uetliberg tunnel components

There are three road crossings for traffic diversion in the event of an incident (accident, fire etc.) and for maintenance work. A crossing is located at each of the two portals and the third is underground in the Reppisch valley ventilation station area. The tunnel itself also has cross-cuts every 300 m to connect the two motorway tubes. Every third cross-cut can be used by vehicles. Both tunnel tubes also have SOS and hydrant refuges at 150 m intervals.

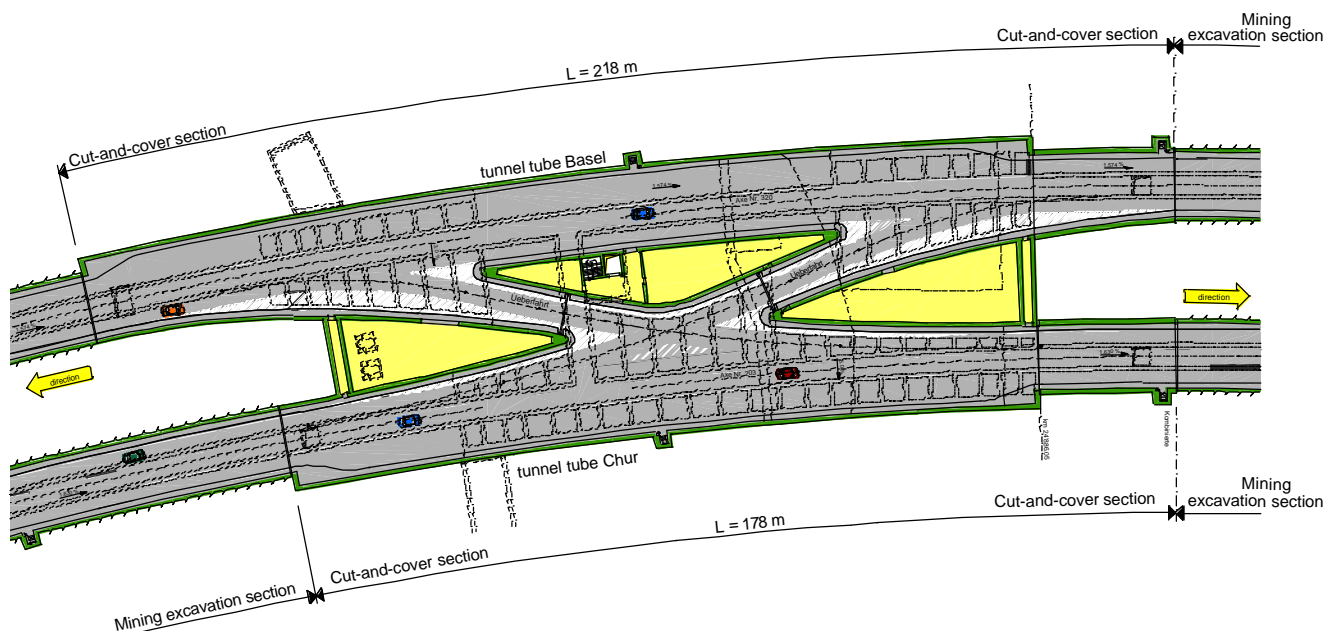


Fig. 3: Plan of Reppisch valley ventilation station

In the Ettenberg section the two tunnel tubes pass underneath the heavily used Landikon tunnel on the SBB Zurich – Zug railway line with a clearance of only 4 – 7 m.

The underground ventilation station is connected to an exhaust vent gallery (cross-section approx. 50 m²) through a vertical shaft (cross-section 47 m²) with an exhaust flue on the Ettenberg. The tunnel is fully ventilated through the underground Reppisch valley ventilation station, from which the exhaust air is extracted via the flue on the Ettenberg.

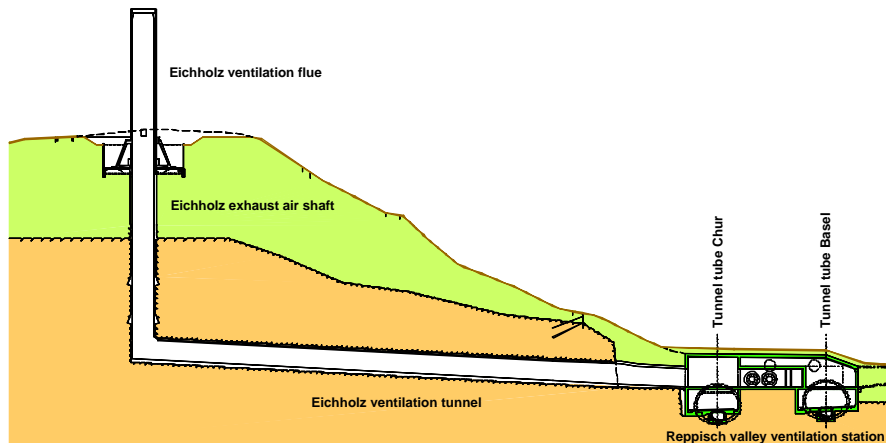


Fig. 4: Section through Reppisch valley ventilation station

Stations are located at the west and south portals of the Uetliberg tunnel. The services are housed in these.

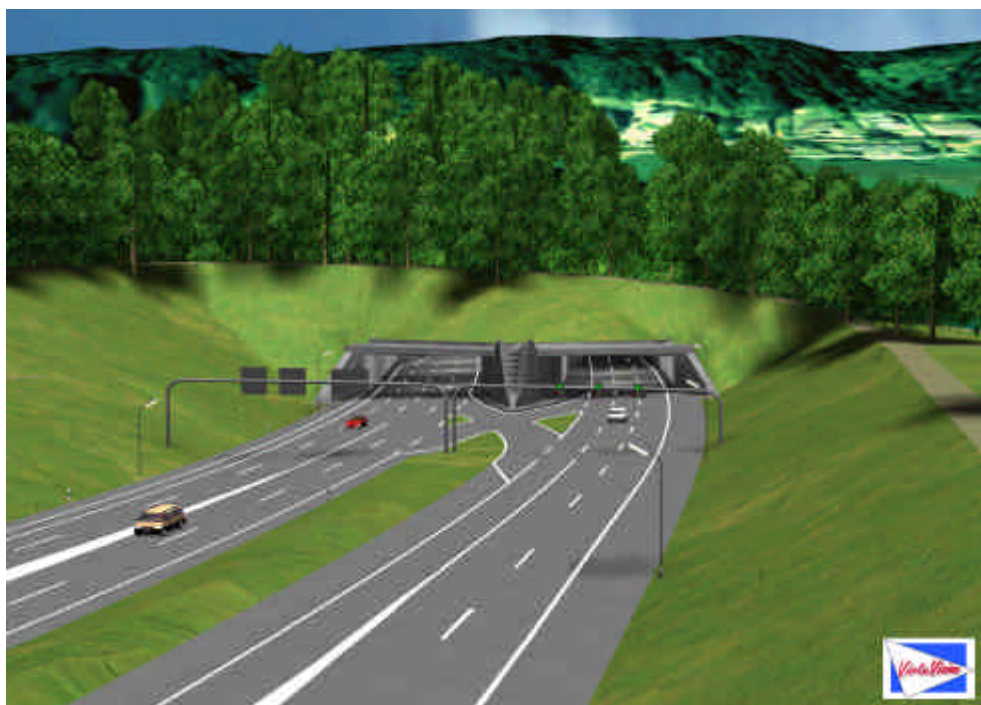


Fig. 5: View of west portal

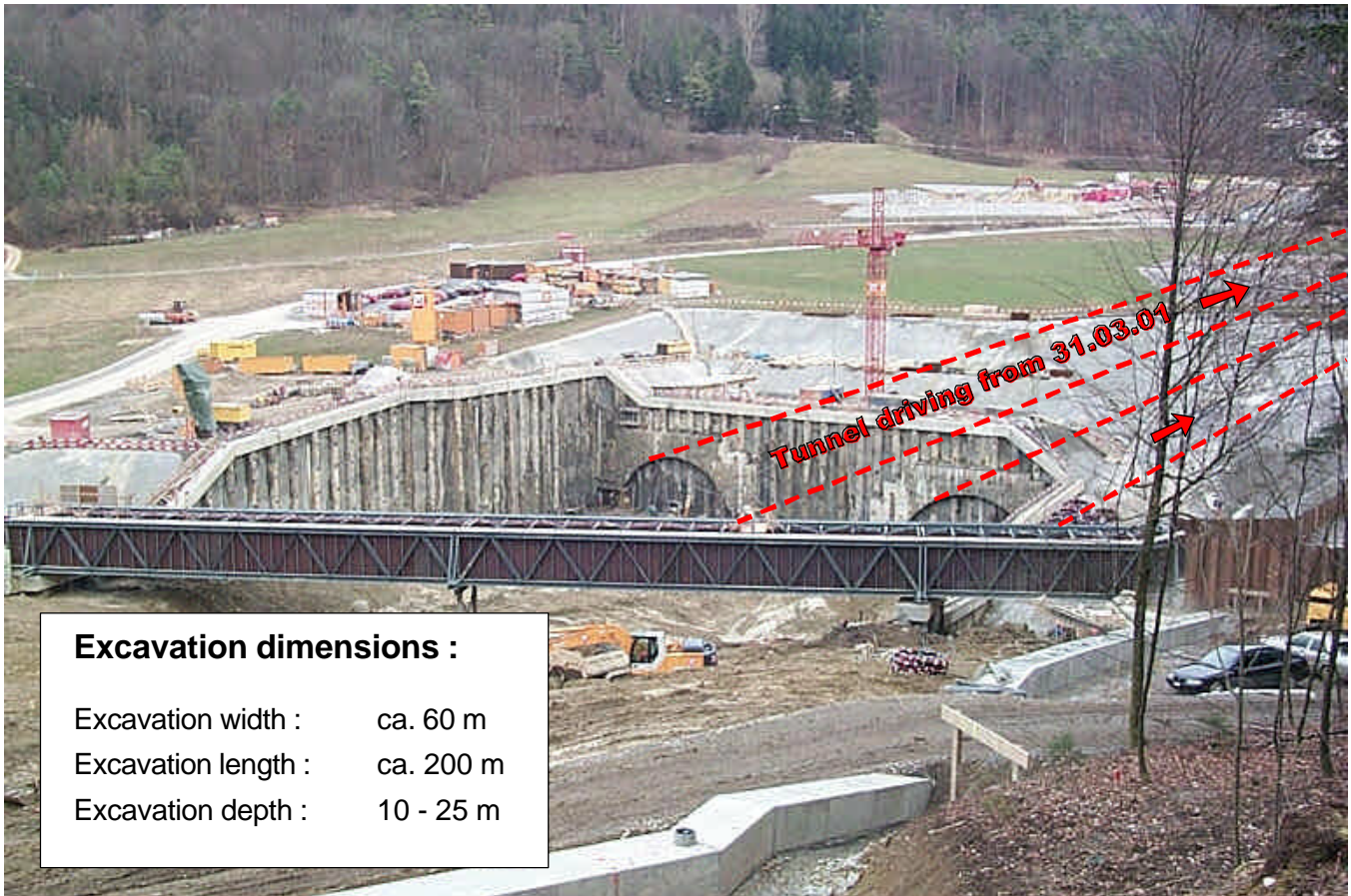


Fig. 6: Reppisch valley cut-and-cover: View to the portal in the Diebis soft ground section

The water from the Reppisch river that crosses the excavation will be diverted over an aqueduct (lattice bridge) above the excavation during the construction period.

4. Logistics / Infrastructure

Construction of the Uetliberg tunnel will produce a total of 1.7 million solid m^3 of borrow and spoil material. Most of the excavated material that cannot be re-used in the project area will be transported by rail to gravel pits in the northern part of the canton of Zurich which have to be filled under official regulations. Suitable rail loading facilities are located on the west and south sides. The facility on the south side has been built jointly for construction of the Uetliberg tunnel and the new Zurich - Thalwil SBB line.

About 70% of the total spoil, representing 1.2 million solid m^3 , is generated by the Reppisch valley cut-and-cover and the tunnelling that starts at that point. This material is transported via a conveyor belt system to the Filderen rail loading facility near the Zurich West interchange. On the return trip the same conveyor belt carries the aggregate for concrete production in the Reppisch valley.

Because there is a hill between the Reppisch valley and the Filderen rail facility, a transport tunnel around 550 m long has to be built for the conveyor belt (70 m in soft ground and 480 m by TBM driving, 3.70 m diameter).

5. Geological summary

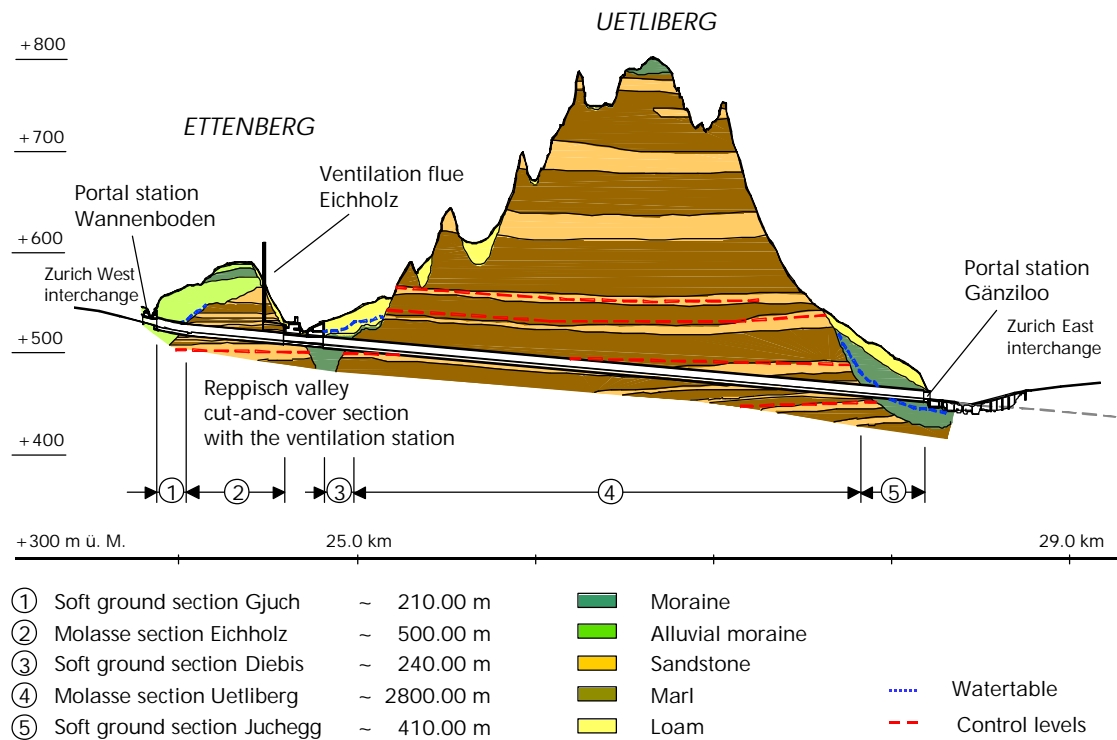


Fig. 7: Longitudinal geological profile

Eichholz and Uetliberg molasse sections

(L = ca. 500 m and 2,800 m) [②,④]

From west to east the Uetliberg tunnel undercuts the two parallel Ettenberg and Uetliberg hills. The core of both hills consists of flat bedded strata of the upper fresh water molasse. The alternation of hard sandstone seams and soft marl strata is typical of this molasse. Secondly, intermediate types of marl sandstones, hard siltstones and sandy marls also occur. The maximum tunnel capping is approximately 320 m. The anticipated water run-off is very low.

Gjuch soft ground section (L = ca. 210 m) [①]

The Gjuch soft ground section (at the Wannenboden west portal) cuts through a very heterogeneous end moraine called the Wettswil moraine complex. It consists of a loamy, sandy gravel.

The water table rises from the centre of the tunnel profile at the start to above the tunnel roof in an easterly direction.

Diebis soft ground section (L = ca. 240 m) [③]

The Diebis soft ground section (east of the Reppisch valley cut-and-cover section) consists of a base moraine overlaid with slope wash. A range of grain sizes can be expected in the base moraine, including stones and rocks. The slope wash consists of moraine material and fine particles. At the start of the soft ground section, about half the tunnel cross-section lies in the slope wash, which then rises towards the

east. After about 50 metres of tunnel, the whole cross-section is in the moraine. In the Diebis soft ground the whole tunnel cross-section is in ground water.

Juchegg soft ground section (L = ca. 410 m) [5]

The Juchegg soft ground section (at the Gänziloo east portal) consists of a base moraine composed initially of sandy-gravels and then of clayey-sands. Above it lies the Uetliberg loam, which goes up to the centre of the tunnel cross-section at the portal. After about 70 metres of tunnel the whole cross-section is in the moraine.

The water table is below the tunnel cross-section at first, rising at the interface between the sandy-gravels and the clayey-sands of the moraine. At the interface between the soft ground and the molasse the whole tunnel cross-section is in ground water.

6. Standard tunnel cross-section

The standard section is divided into 3 parts:

- Road area
- Exhaust air duct (separated from the road area by a false ceiling)
- Substructure with service duct

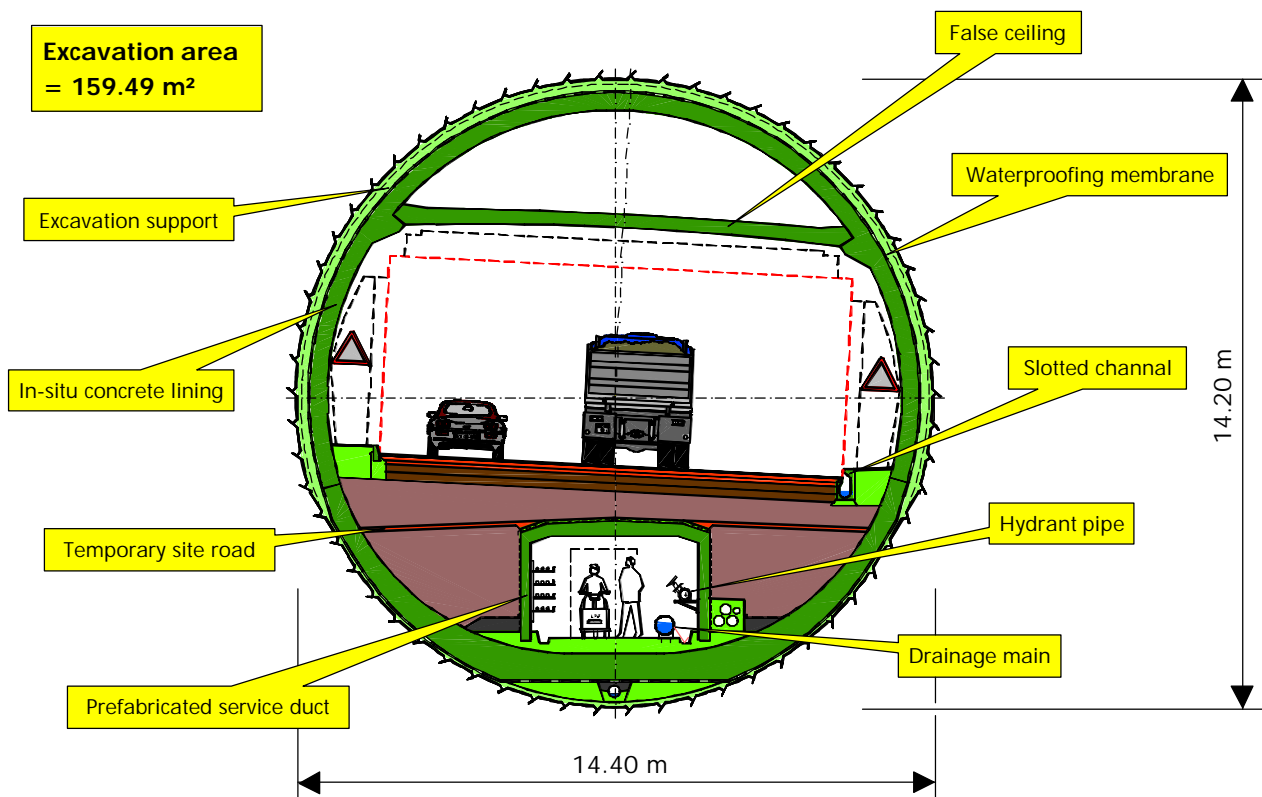


Fig. 8: Standard section in Uetliberg molasse

The standard cross-section in the Uetliberg molasse section is 14.40 m wide and 14.20 m high. The excavation area is approximately 160 m².

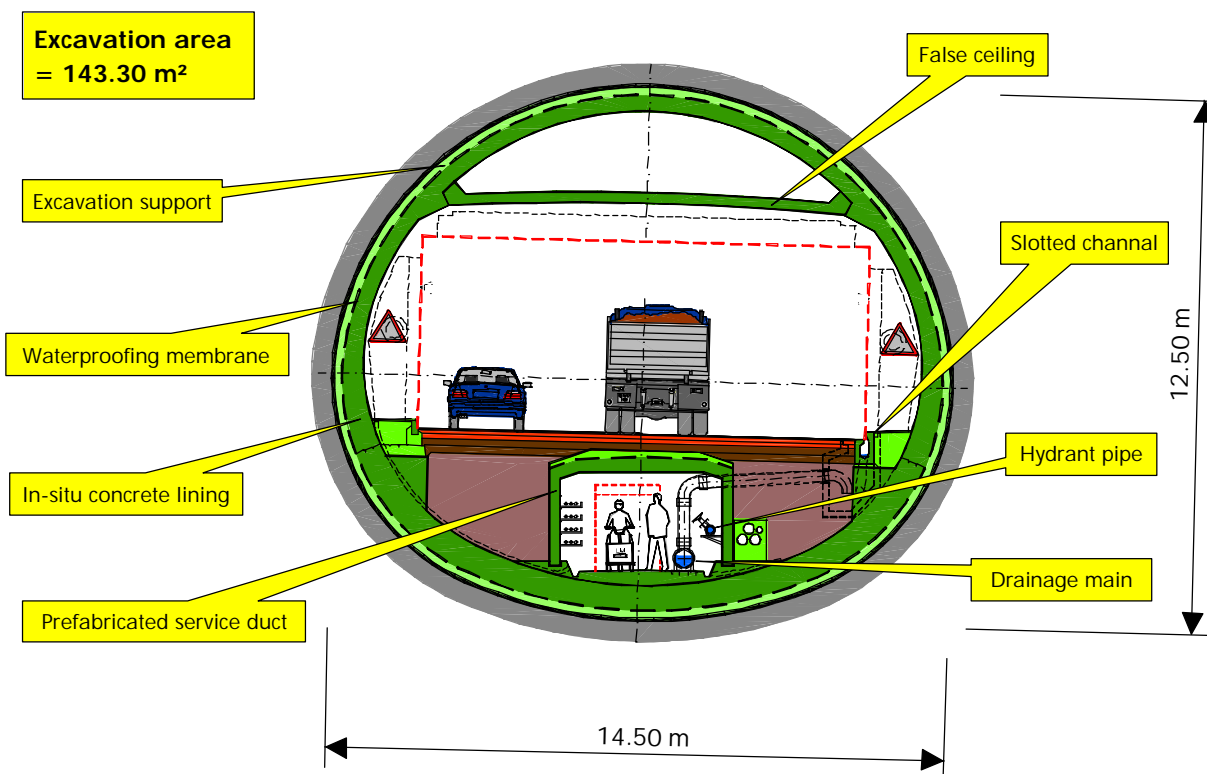


Fig. 9: Standard section in Eichholz molasse and soft ground sections

The horseshoe cross-section is 14.5 – 14.7 m wide and 12.5 – 12.7 m high. The excavation area is 143 - 148 m².

Each tunnel tube has two lanes and a hard shoulder with a total carriageway width of 10.5 m. The camber is 2.5% on the straight and up to 5% on the bends. There are 1 m wide verges for walking on both sides of the carriageway and slotted channels for carriageway drainage and discharge of liquids after accidents.

The service duct carries the hydrant pipe, the main carriageway drainage pipe and electromechanical equipment.

The lining to all the tunnels is double skin with full sealing. The seal is pressure-maintaining in the soft ground and Eichholz molasse sections (Fig. 9) and drained (unpressurized) in the almost dry Uetliberg molasse section (Fig. 8) – due to higher slope water pressure.

7. Operational tunnel ventilation

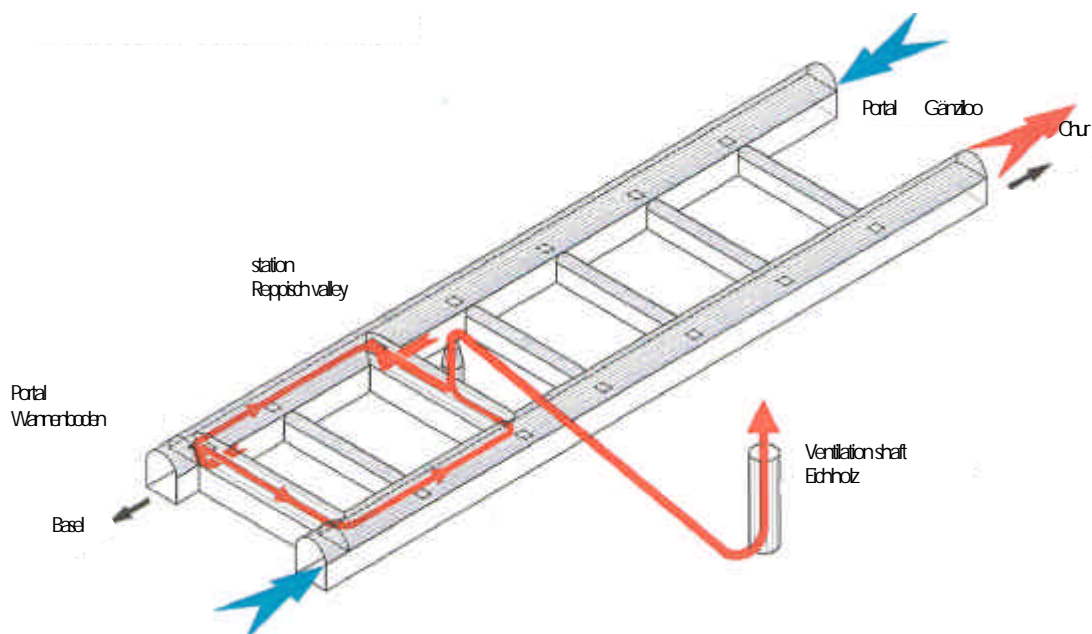


Fig. 10: Tunnel ventilation in normal operation: Flowing maximum traffic

The system used is longitudinal ventilation. In normal operation there is one-way traffic in both tubes. The air flow is generated by the natural piston action of the vehicles. The exhaust air from the Chur tube which falls from west to south flows out freely at the portal.

In traffic queues or fires, the exhaust air is extracted through openings in the false ceiling of each tube and in the portal area and carried via the Reppisch valley ventilation station to the Eichholz exhaust air shaft and ventilation flue.

At the west portal, constant emissions of tunnel air from the upward Basel tube have to be avoided for environmental reasons. The exhaust air from this tunnel is therefore collected at the Reppisch valley ventilation station and the west portal and extracted through the exhaust air shaft.

8. Cost

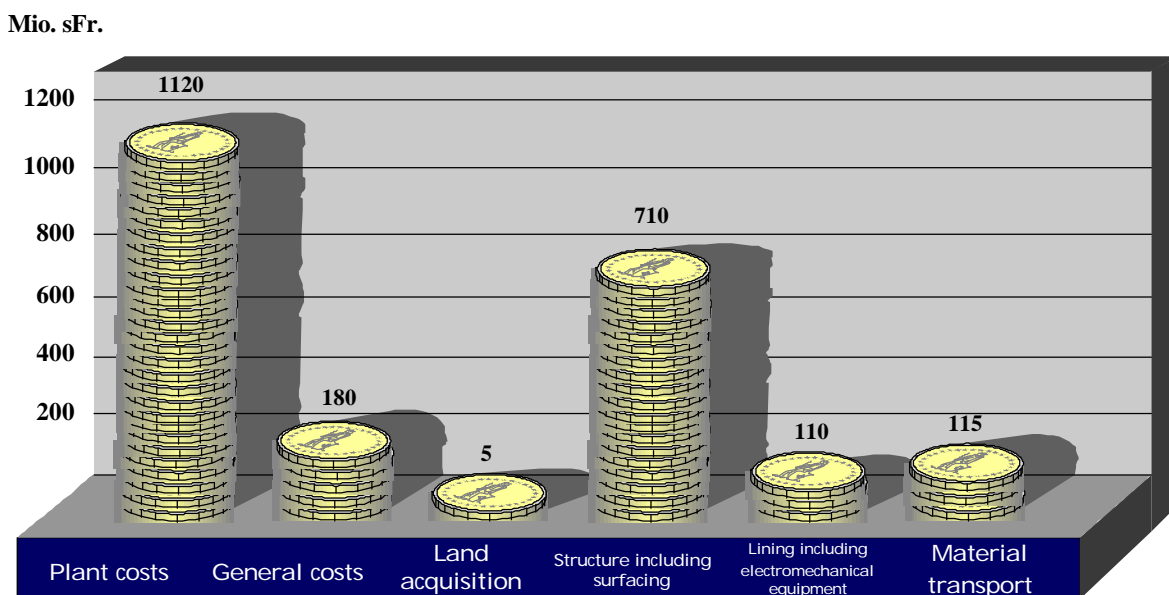


Fig. 11: Total Uetliberg tunnel cost (price basis 1994)

The total cost of the Uetliberg tunnel is CHF 1.12 billion (excl. ancillary structures to the east and west). Project planning and supervision make up CHF 180 million. The actual tunnel structure including surfacing, portal structures and ventilation station, is estimated at CHF 710 million

9. Uetliberg tunnel construction programme

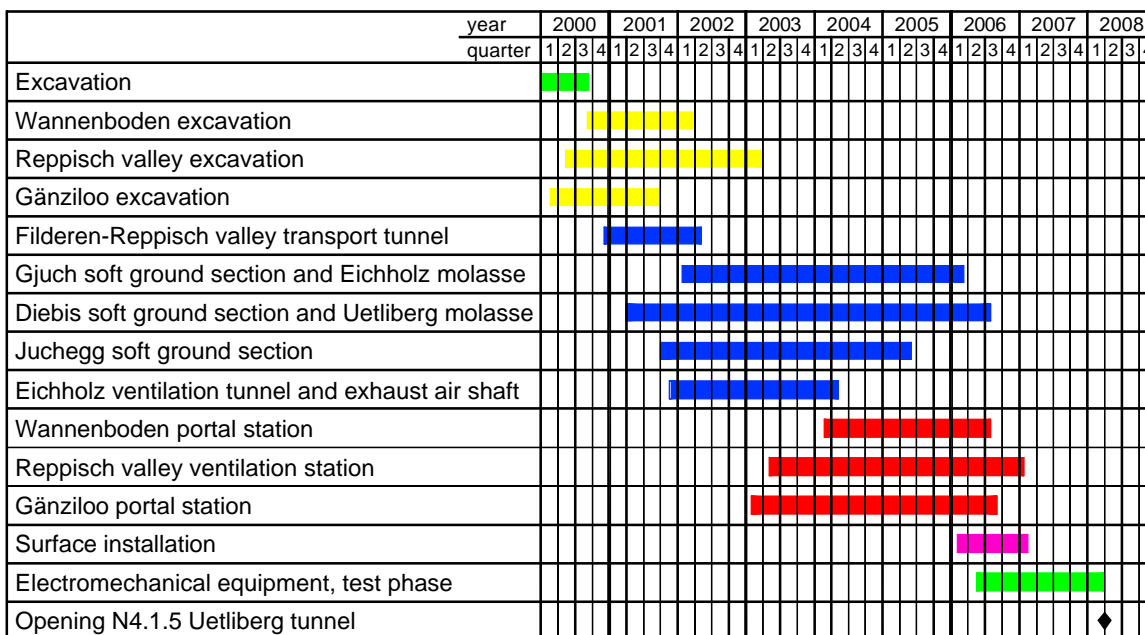


Fig. 12: Compressed Uetliberg tunnel programme

The structural work for the Uetliberg tunnel was put out to public tender at the end of September 1999 and tenders had to be submitted in March 2000. The tender review and award of the tunnelling works were completed by end September 2000.

The **main tunnelling works** were awarded to the Uetli joint venture in September 2000 to enable them to start on schedule in Spring 2001. The start of transport tunnel construction was moved forward to 2000.

Technical commissioning of the Uetliberg tunnel is now expected in 2008, 2 years earlier than originally planned.

B. Tunnel construction

1. Sequence/programme of excavation

The 4.4 km long Uetliberg tunnel will be driven from three different starting points.

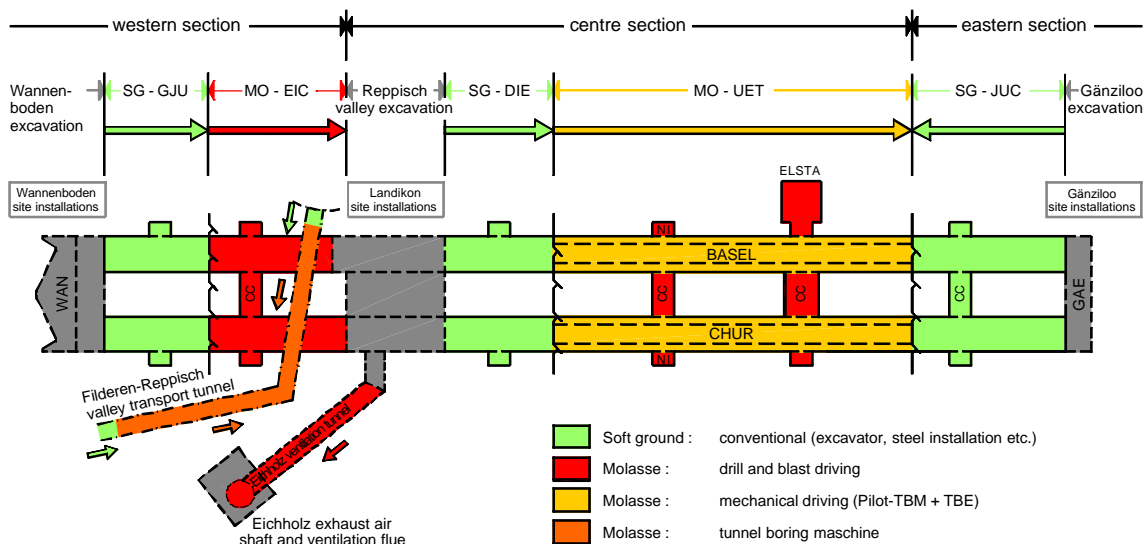


Fig. 13: Diagram of the heading programme

Western section:

The **Gjuch soft ground section** (2 x 210 m) in the west will be driven downward from the Wanneboden excavation by conventional core boring and steel installation as far as the Eichholz molasse (estimated daily progress over the whole soft ground section: 1.4 m per working day). Some large-scale support measures will be necessary to cut through these ground conditions which are geotechnically extremely difficult (injection, water table lowering, preliminary drainage bores etc.).

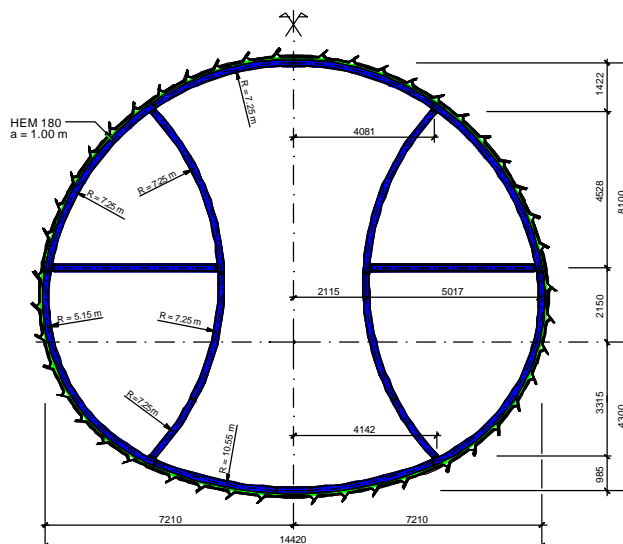


Fig. 14: Excavation support in the Gjuch, Diebis and Juchegg soft ground

The excavation support consists of steel segments (HEM-180 beams at 1 m centres) and 25 cm thick steel-fibre reinforced shotcrete.

The **Eichholz molasse section** (2 x 500 m) will be excavated by blasting in the extension of the Gjuch soft ground. The tunnel will be driven by blast/drill, divided into crown, bench and invert. The rock support is generally mesh-reinforced shotcrete and rock bolts.

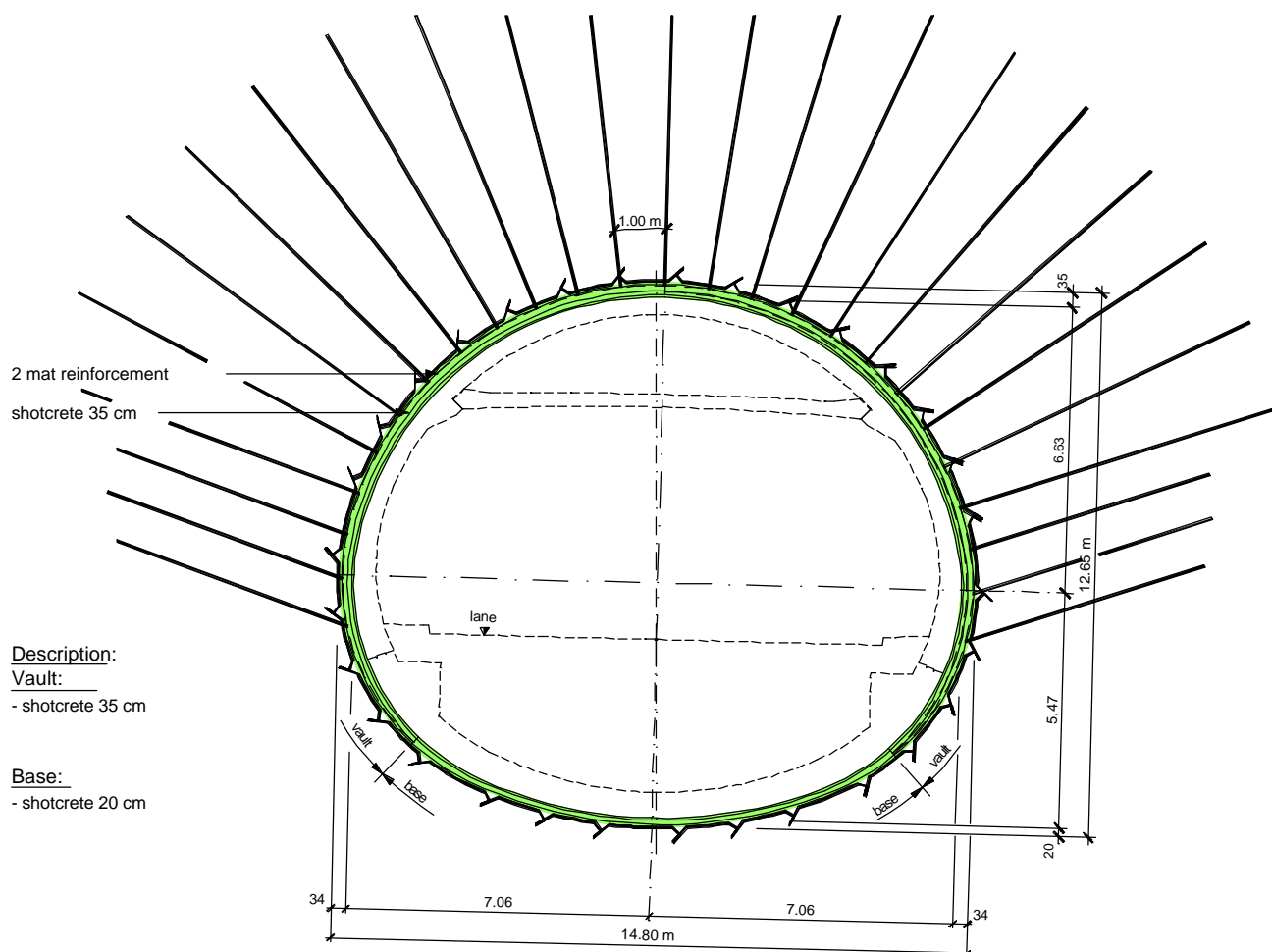


Fig. 15: Eichholz molasse: Cross-section division and support system

In critical areas, particularly in the section driven under the Landikon tunnel, steel installation is specified. Large-scale stabilisation work will also be carried out beforehand in the rail tunnel. Breakthrough of the two motorway tunnels to the Reppisch valley excavation is expected in July 2003 and April 2004.

Centre section:

From the Reppisch valley excavation (total spoil 270,000 m³, 1,000 bolts, 3,100 metres of bored piles, to be completed in phases by 2003), the tunnel will be driven downward under the Uetliberg to the Zurich South interchange. Starting in March 2001, the two tunnel tubes (2 x 240 m) will first be driven in the Diebis soft ground section by core boring. As soon as the north tube (Basel tunnel) reaches the rock in February 2002, a tunnel boring machine (TBM, diameter 5.00 m) will be set up. It will be used to drive a pilot tunnel through the whole Uetliberg molasse section (2,800 m). When this is cut, the TBM will be

taken away and moved via bypass to the end of the second tube in the Diebis soft ground section. After reassembly the TBM will start again and drive the pilot tunnel for the south tube (Chur tunnel) between November 2002 and July 2003.

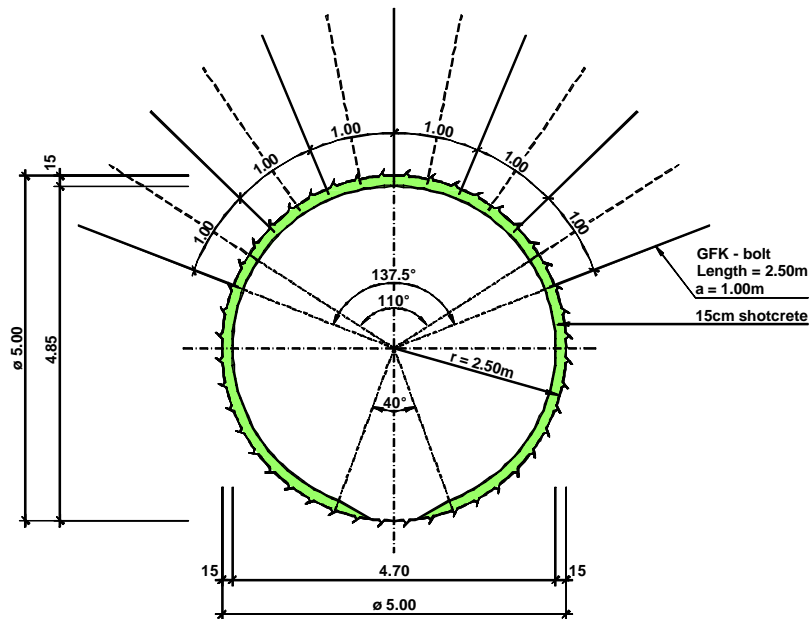


Fig. 16: TBM pilot tunnel cross-section (Diameter 5 m with support system)

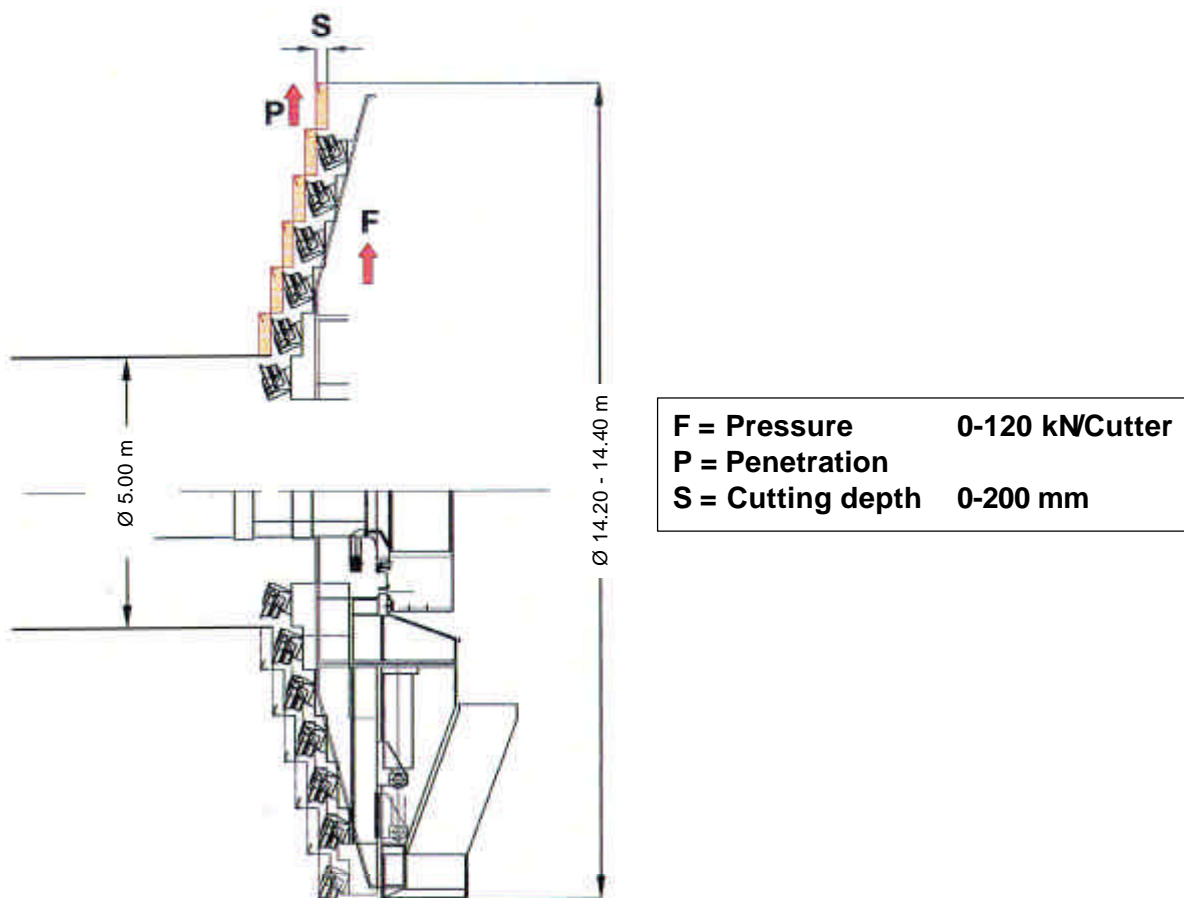


Fig. 17: TBE undercutting system (Diameter 14.20 m)

While TBM driving continues in the north tube (diameter 5.00 m), a tunnel bore extender (TBE) with undercutting system will be installed in a starting cavern at the end of the Diebis soft ground section (variable cutting diameter 14.20 to 14.40 m). The TBE will be used to widen the north tube to its full cross-section from October 2002 to March 2004. The machine will be braced in the pilot tunnel already cut.

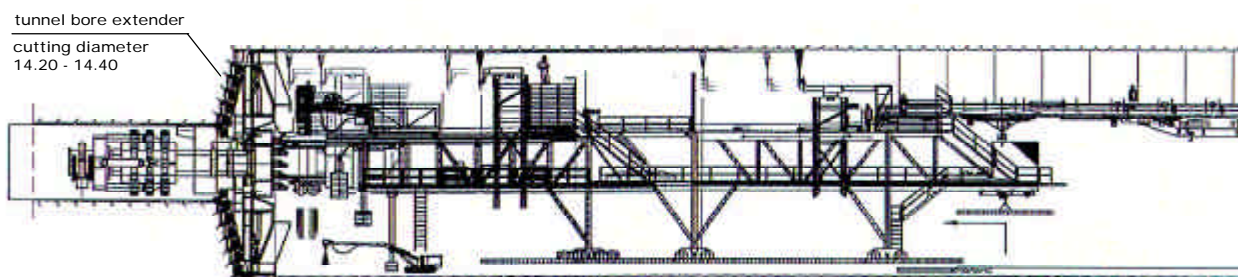


Fig. 18: TBE driving with undercutting system and installation of support in follow-on

After driving the north tunnel, the TBE will be taken away from the tube and moved via the Reppisch valley excavation to the second starting point at the south tube. The south tube (Chur tunnel) will then be widened from May 2004 to September 2005. The excavation support consisting of mesh-reinforced shotcrete and bolts will be installed in follow-on 1 and 2. In follow-on 3 the invert and service duct (prefabricated unit) will be installed and backfilled with prepared molasse material.

Eastern section:

Separately from the centre section, the Juchegg soft ground section will be driven upward from near the Zurich South interchange, starting at the south portal, by a similar method to the western section (core boring). Both tunnel tubes will be excavated by about the middle of 2003. The interior lining in this section, including the false ceiling and portal structures will be completed by the end of 2004 or 2005.

The south side differs from the other soft ground sections in that the Uetliberg loam has to be crossed. In the first 70 m of tunnel heading, a pipe pile system will be installed for support (in 6 x 12 m stages) in addition to the steel rings used in the other soft ground sections.

2. Preliminary works by other contractors

To save time, the site installations, preliminary cuts and parts of the excavations described below were put out to tender separately from the main Uetliberg tunnel package and completed in advance. The purpose was to make sure the tunnelling contractor could start the actual tunnel driving work after a relatively short preparation period in Spring 2001.

Site installations:

To construct the Uetliberg tunnel, installations were set up at each portal in addition to the main installations in the Reppisch valley (Landikon site installations). These areas were planned and installed in two phases. Construction of the 1st phase in the Reppisch valley and at the west portal is complete and comprises the following works:

- Treatment facilities for the tunnel, excavation and surface water
- Drainage systems with storm water and foul water pipes
- Surfaced site road systems
- Preparation of connections for site water and power

Preliminary cuts and parts of excavations:

Another contractor completed the preliminary cuts and parts of the excavations at the west and south portals. On contract award to the tunnel contractor, who had to tender for deepening of the excavations (2nd phase), the work passed from the other contractor to the tunneller.

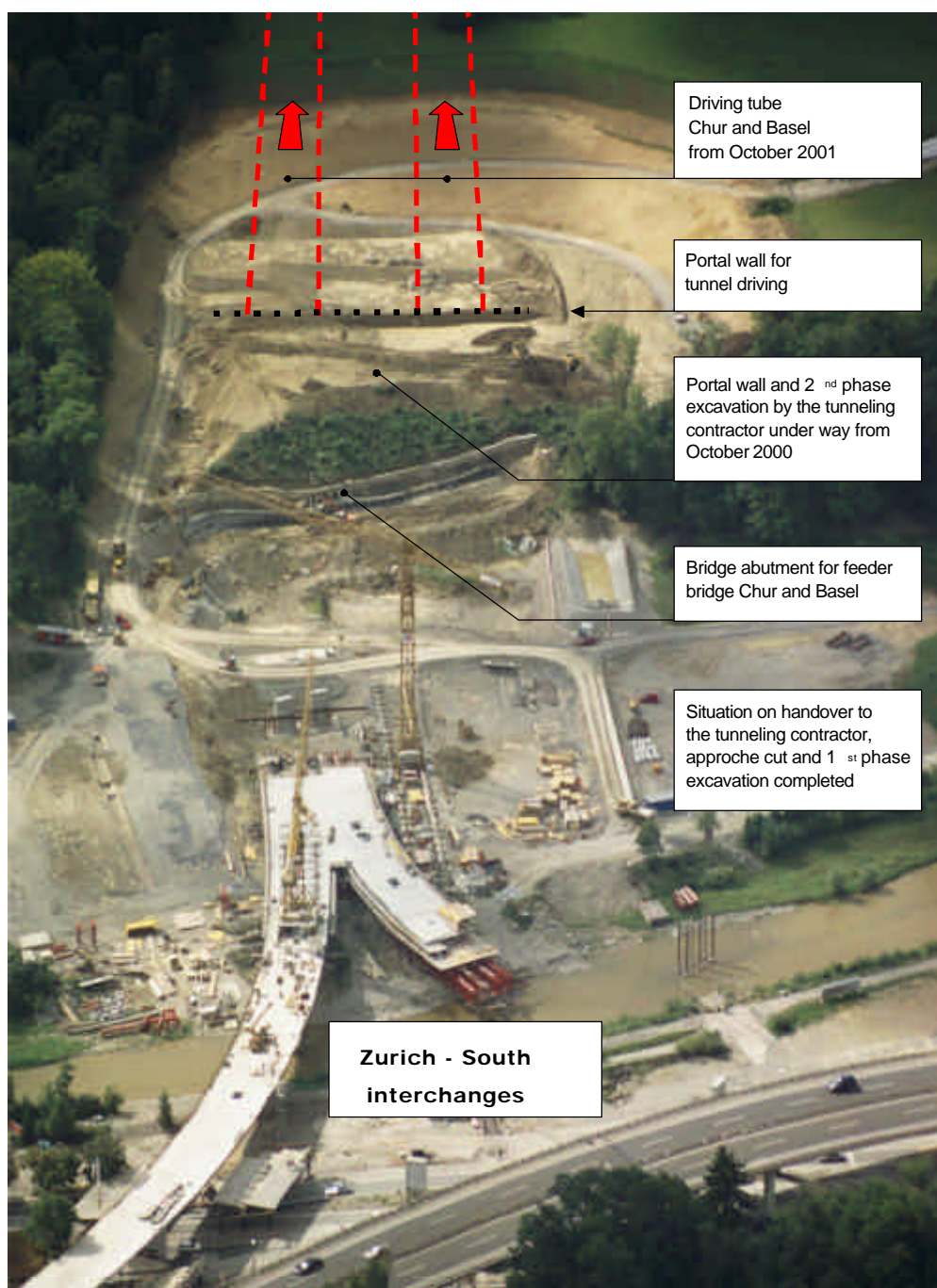


Fig. 19: View of Gänziloo preliminary cut

Reppisch valley excavation:

The Reppisch valley excavation is being completed as a package by another contractor. The excavation work will continue until 2003 in parallel with the tunnel driving.

Ecological measures:

When the site installations were constructed, landscape protection, the environmental aspects and soil protection all had to be taken into consideration. In Landikon, for example, this is being done by maintaining wild life corridors along the Reppisch and its tributaries. Further biotopes are being established and will remain in place when all the work is completed so that the biodiversity of local wild life is preserved. Reptile-friendly habitats will be preserved or created when the interim spoil storage


embankments are set up by varying the slopes and incorporating gravel layers in some places. The aim of these and other similar measures is to cause as little damage as possible to the existing ecology.



Fig. 20: Diverted course of the river Reppisch in the new bed

The course of the Reppisch was diverted to an aqueduct to allow the ventilation station and tunnel to be built. From the end of the aqueduct, a completely new course with low-water channel has already been made to enhance the landscape. The course of the river will be replanted in Spring 2001. When construction is complete, the river will be rediverted to a meandering course above the ventilation station infrastructure.

Other project links:
www.amberg.ch
www.uetlibergtunnel.ch

	
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