

# Complicated excavation altering an existing tunnel – the west portal of the Visp by-pass tunnel, Switzerland

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**ABSTRACT:** As one of the last sections of the A9 Motorway through the Upper Rhone Valley, the by-pass around the city of Visp is currently under construction, comprising of two blast-and-drill tunnels of 2.7 km and 4.2 km respectively. The shorter tunnel is the more demanding one, as an existing old tunnel is to be incorporated into one of the two tubes while staying in use. This creates a delicate situation at the north portal in terms of construction sequence and slope stability. These factors are discussed in this paper.

## 1 PROJECT OVERVIEW

### 1.1 Traffic situation in the upper Rhone valley

When completed in 2017, the Visp by-pass will link the Rhone Motorway A9 from Lake Geneva with the Simplon pass and alleviate the densely populated town of Visp from the commuting traffic to and from Brig (A9-VS). As the industrial area north of Visp makes it difficult to accommodate a 4-lane motorway, it was decided to place the by-pass south of the town in the mountains which mark the junction of the Saas valley with the Rhone valley (Fig. 1).

### 1.2 Altering an existing tunnel

The two tunnels, the 2.7 km long tunnel Visp to the west and the 4.2 km long Eyholz tunnel to the east, are linked by a bridge crossing Staldbach creek. Tunnel Visp is the shorter one, but has to integrate an existing single-tube tunnel via an underground junction, which will stay in use during construction as access/exit tunnel into the Saas valley and accommodate the tourist traffic toward the well-known skiing resorts Zermatt and Saas Fe.



Figure 1. Situation of the Visp by-pass with underground junction (lower left) and portal "Schwarzer Graben" (upper left).

Apart from the caverns necessary for the underground junction and the connecting tube overpassing the new motorway, an unusual design problem is posed by enlarging the existing Vispertal tunnel to become the south tube of the motorway. At the northern portal, called Schwarzer Graben ("black trench"), the alignments of the old and the new tunnel deviate by a small angle, necessitating the partial demolition of heavy steel supports of the old tunnel, close to the surface of a steep, weathered rock slope (Fig. 2).

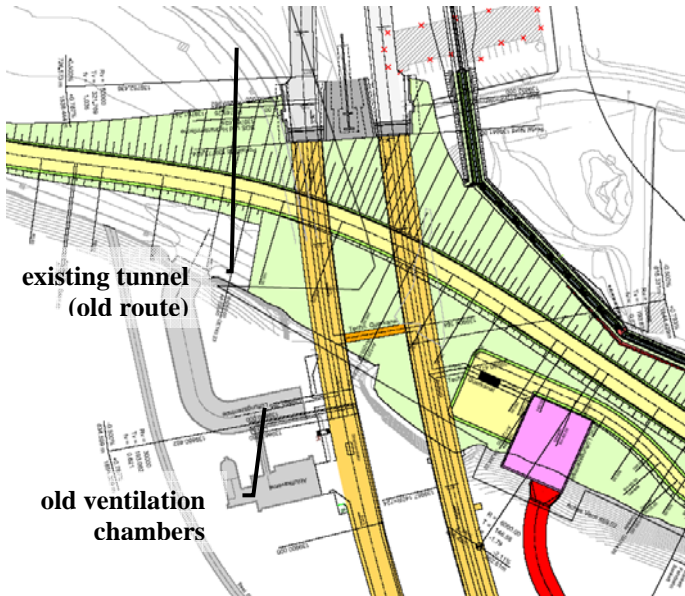


Figure 2. New tunnel portal with the existing old Vispertal tunnel and the old ventilation chambers to be replaced.

The stretch between the underground part and the final portals will be constructed as cut-and-cover tunnels, with the cantonal road to Visp running over the land fill.

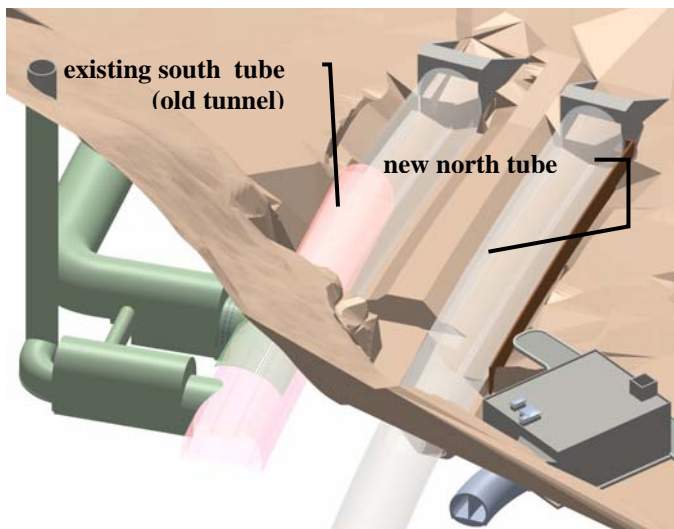


Figure 3. Computer-aided model of the construction pit for the cut-and-cover tunnels.

The old ventilation chambers will be taken out of service and replaced by new electromechanical facilities above ground at the right-hand side (Fig. 3).

To construct the approach tunnels by cut-and-cover, the rock slope needs to be cut back considerably, leading to a construction pit with an approximately 23 m high, skewed rock slope (cf. Fig. 7 below). This requires anchoring of the slope in a crosswise pattern, complicated by the existing tube and the presence of the old ventilation chambers.

## 2 GEOLOGY AND GEOTECHNICS

### 2.1 Earth works

A large part of the excavation for the new portals will be done in mantle rock and back-fill of the old tunnel tube, crossed by the existing cantonal road to Visp. The widening of the existing tube and the new back-anchoring of the cut will be situated in micaceous limestone schist.

### 2.2 Stress state

The stresses in the portal zone have already undergone several redistributions due to the construction works for the old tunnel tube and the associated ventilation chambers, as well as due to the driving of a pilot and muck gallery running adjacent to the location of the new north tube,

The parent rock is of fairly good quality, but the prior construction work is expected to have broken up the original formation considerably, which already had experienced heavy folding in its geotectonic past, resulting in a low GSI value.

## 3 CONSTRUCTION SEQUENCE

### 3.1 Phasing of operations

The many constraints involved, such as the location of the cantonal road, the geotechnical conditions, the integration of the existing tunnel tube, and its enlargement to accommodate a draw-in for maintenance vehicles all result in a complex sequence of works. Two principal periods with seven phases in total are distinguished:

1. Enlargement of the pilot gallery to become the new north tube (construction 2012-2013)
  - phase A.1: exterior cut-and-cover section for the north tube (and new portal south tube)
  - phase A.2: exterior cut-and-cover section for the south tube (Vispertal tunnel closed)
  - phase A.3: provisional re-opening of the Vispertal tunnel
  - phase B.1: opening of the re-located cantonal road crossing the new cut-and-cover tunnels.
2. Reconstruction of the existing tunnel to become the new south tube (construction 2015-2016)
  - phase B.2: opening of the new north tube and demolition of the old Vispertal tunnel portal

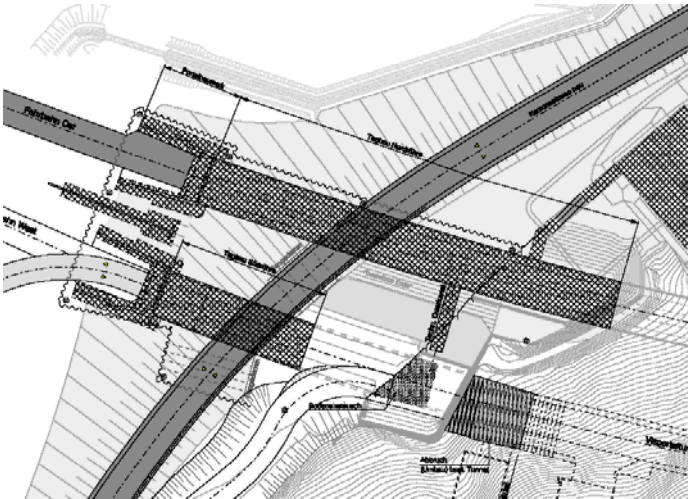
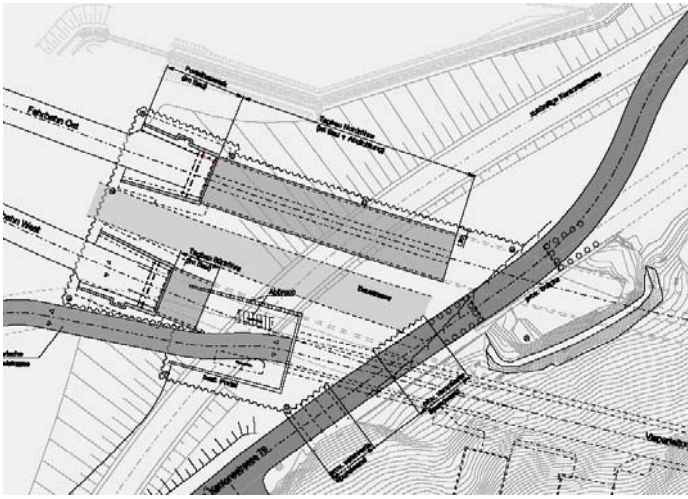


Figure 4. Construction phase A.1 with traffic trough the old tunnel (top) and C.1 after opening of the north tube (bottom).

- phase C.1: alteration of the old south tube
- phase C.2: closure of the cut-and-cover gap to link up with the south tube.

### 3.2 Excavation for the south tube (phase B.2)

Prior to removing the backfill of the existing tunnel, a rock fall protection barrier is installed above the slope and additional rock anchoring will be drilled to secure the old cut. To allow the demolition of the existing cut-and-cover section of the Vispental tunnel, the traffic will be re-routed through the new northern tube and the Vispental tunnel be taken out of service. The replacement of the old cut-and-cover section will be done in two stages in order to allow shifting of the cantonal road to its final position across the new cut-and-cover sections.

A special challenge is the deconstruction of the massive supporting arch of the old tunnel in the mantle rock, with a side gallery extending into the old ventilation chambers (Fig. 5). The arch is made of heavy rolled steel sections and needs to be partially preserved but widened with a shotcrete lining to accommodate the tunnel re-alignment by 1 m and a new draw-in bay for vehicles. Moreover, the new

tunnel base will be deeper than the existing one to provide space for drainage and other utilities.

The rock pillar between the tubes, which has a free surface towards the cut-and-cover section of the north tube, will be stabilized by grouting through drilled injection anchors. This work is performed in advance with the tunnel cladding removed.

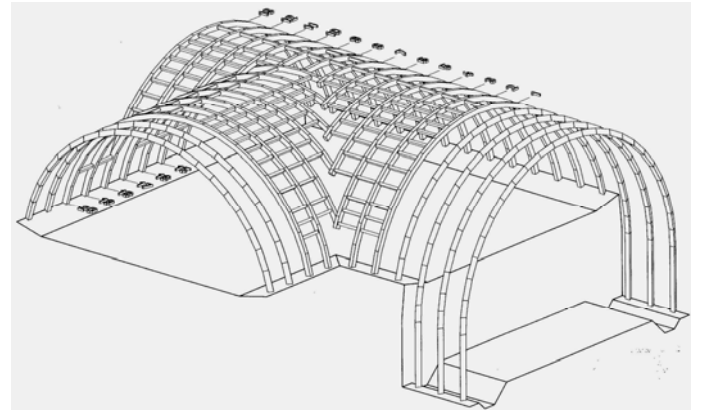


Figure 5. Massive supporting steel sections in the old Vispental tunnel, with gallery to the old ventilation chambers (left).

### 3.3 Refurbishment of the old tunnel (phase C.1)

The deepening of the existing tunnel by 5 m may require additional supporting measures, depending on the actual degree of rock deterioration found behind the old steel sections. If the conditions encountered are worse than predicted in the geological report, the refurbishment might be done under the protection of a pipe roof support system.

## 4 3D COMPUTATIONAL MODEL

### 4.1 Geometry

The stability analysis of the rock slope and the weak pillar between the north and the south tube is challenging. The influence of the existing Vispental tunnel and the side gallery into the old ventilation chambers needs to be adequately modeled, even though the construction sequence and associated stress redistribution of building the old tunnel – and in effect already the primary stress state in the steep mountain side – can just approximately be evaluated. The widening and deepening of the old Vispental tunnel over a length of 30 m will result in further stress redistributions which will affect the slope support.

Of course, the possible pattern of rock anchors is also constrained by the existing underground structures. With regard of the attainable precision of boring, a minimum distance of 3 m from existing structures is deemed necessary.

## 4.2 Finite element models

The preliminary computations were performed with a slice of finite thickness located about 8 m inside the rock section (Fig. 6). The software code used is the Z\_SOIL.PC program by ZACE SA, Version 7.3 (Zimmermann & Truty 2006).

The excavation of the construction pit for the north tube and the anchoring of the rock slope next to the existing Vispertal tunnel were simulated. The objective was to verify the geotechnical parameters of the micaceous limestone schist and to obtain a first assessment of the anchor forces required as well as the stress changes in the rock pillar due to widening of the old tunnel. An isotropic Mohr-Coulomb type constitutive model was used for the rock, neglecting the existence of joints, which are inclined favourably.

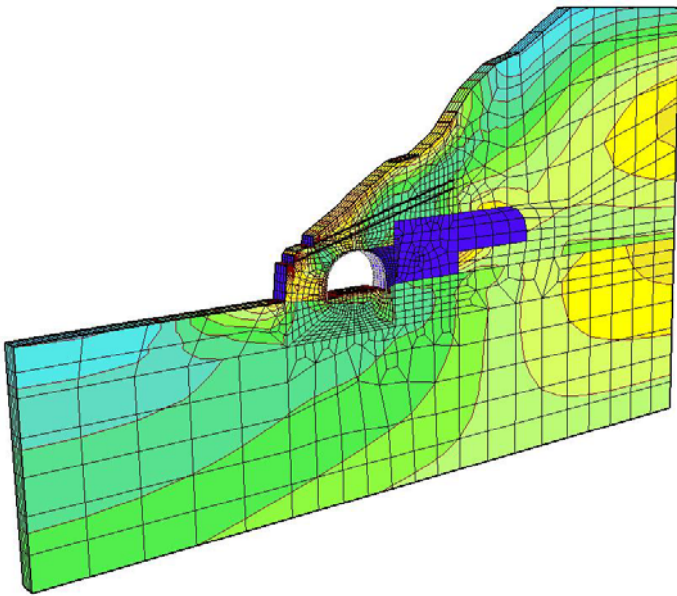
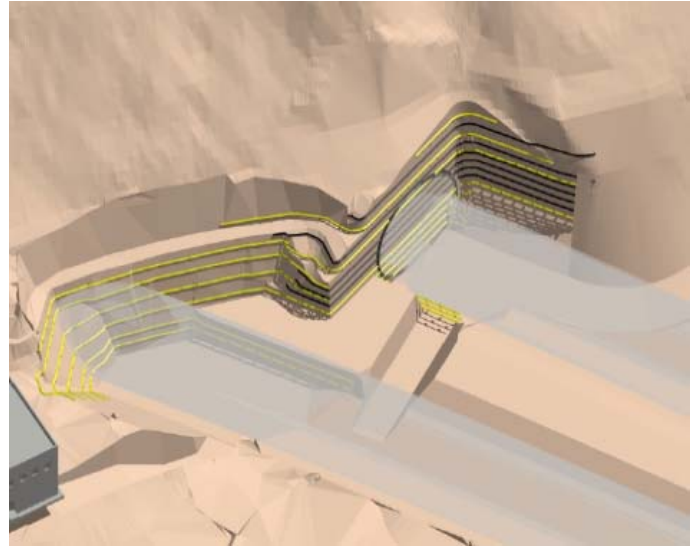


Figure 6. FEM model of a slice through the existing Vispertal tunnel, showing the old ventilation chambers in dark color.

The complex geometry led to the decision to analyze the rock stability in depth by means of a 3D finite element model over an area of 100 m by 100 m. Beginning with the present geometry of the excavation pit for the new north tube, a simulation of the removal of the backfill around the cut-and-cover section of the existing Vispertal tunnel and of the stabilization of the rock slope will be undertaken. The excavation will be done in 3 m steps for each anchor layer, a 5 m step to the foundation level of the existing cut-and-cover tunnel and a further step to the new foundation level.

The shotcrete stabilization of the rock slope will be modeled by elastic concrete shell elements which also represent the distributed rock bolting in between layers of rock anchors. The pre-stressed rock anchors are explicitly modeled as elasto-plastic truss elements of 1.5 m spacing, which can be oriented in any direction as required by the existing under-



ground structures and pre-stressed to the specified force.

Figure 7. Close-up of the excavation pit with layers of rock anchors (south tube of the existing Vispertal tunnel in the rear).

The lining of the existing Vispertal tunnel and the side gallery to the old ventilation chambers will also be modeled by shell elements. The interface to the rock continuum will only transmit radial forces but no friction in order to represent the plastic sealing membrane between concrete and rock. The 3D FEM model allows to analyze the effect of the cross-wise pattern of rock anchors around the corner of the rock pillar and to optimize their orientation and length (Fig. 7).

## 5 MONITORING

The excavation and refurbishment works will be accompanied by a monitoring concept, involving the mountain side above the excavation, the excavation pit and the vulnerable rock pillar by means of 3D reflecting mirrors. In addition, the anchor forces and the deformations in the old ventilation chambers will be monitored.

If the measurement readings were to indicate that the rock anchors are not able to restrain the rock deformations within acceptable limits, additional stabilization measures are foreseen from inside of the old ventilation chambers.

## REFERENCES

- [www.A9-VS.ch/fr/](http://www.A9-VS.ch/fr/). Page internet de l'autoroute A 9, Contournement Sud de Visp. Routes Nationales du canton du Valais.
- Zimmermann, Th. & Truty, A. 2006 (eds). *Numerics in Geotechnics and Structures, 1985-2005, 20 years Z\_SOIL.PC*. Lausanne: Elmeppress International.