Zeitschrift: IABSE structures = Constructions AIPC = IVBH Bauwerke

Band: 10 (1986)

Heft: C-37: Protective structures: Part I

Artikel: Three different types of anchored rock fall and avalanche protection galleries (Switzerland)

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DOI: https://doi.org/10.5169/seals-19864

5. Three Different Types of Anchored Rock Fall and Avalanche Protection Galleries (Switzerland)

Introduction

The static and dynamic loading on road protection galleries can be of different types. Whereas galleries to protect against rock falls are subjected mainly to concentrated forces from falling rocks, avalanches produce mainly compressive and tensile forces as the avalanche flows over the gallery, together with large static loadings due to the snow which remains. Both of these force systems can be economically resisted by anchoring the galleries into the rock by post-tensioned anchors.

In the design of a gallery, two mutually contradictory requirements must be considered: On the one hand the large loadings call for a large number of support points (if possible also on the downhill side), but on the other hand a «forest of columns» is undesirable for optical and aesthetic reasons and indeed in many cases a support on the downhill side must be avoided altogether, on account of the geometrical und geological circumstances.

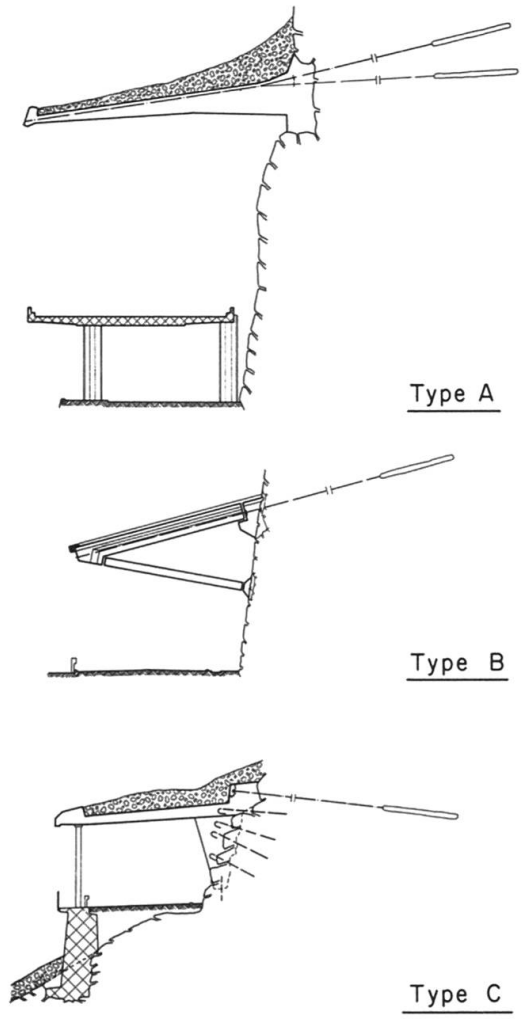

Fig. 1 Basic principles of the three forms of construction of rock fall and avalanche galleries

Three basic types of construction for rock fall and avalanche galleries can be considered. These are illustrated in Fig. 1. Type A was used, for example, for the rock fall gallery N2 Lopper (Canton Nidwalden), Type B on the Axenstrasse (Canton Schwyz) and in the «Les Grands Rochers» region (Aigle-le Sépey road, Canton Vaud) and Type C for the galleries «Zur Eich» (Jaunpass-Strasse, Canton Fribourg) and «Fehdenwald» (Sustenpass-Strasse, Canton Uri). An example of each type will be briefly described below.

Rock fall gallery N2 Lopper

The choice of a cantilevered, post-tensioned, anchored gallery arose from the following limiting conditions: National Highway N2 had to be kept open continuously, except for short night-time closures. The Cantonal Highway also could only be closed to a limited extent. On neither of these roads could falsework supports be permitted.

A part of the gallery is designed as a deflecting structure, i.e. the falling rock is deflected into the lake, and the remaining part as a capture structure, i.e. the rock remains on the roof. The following loadings were used in the static design:

- Permanend loads, i.e. self-weight, insulation and earth cover
- A uniform live load (rock debris and snow) of 2 kN/m²
- Rock fall:
  a) for the deflector structure, in the form of a rock of 2 m³ volume falling from a height of 50 m or a layer of rock debris uniformly distributed over a width of 20 m and having a volume of 50 m³
  b) for the capture structure, in the form of a rock of 0.25 m³ volume, falling from a height of 100 to 150 m

  The rock fall loading was considered as an exceptional effect, and therefore the admissible stresses could be increased for this load case.

The gallery consists of two sections, totalling approx. 155 m in length. The slab is cantilevered a maximum of 18.20 m. At the free edge its thickness is 0.58 m and at the point of fixity to the rock it is up to 3.58 m deep. The slab was post-tensioned with VSL tendons, which were coupled to the rock anchors.

The rock anchors have the following characteristics: Type VSL 6-19, breaking force 5,000 kN, working force 2,500 kN, test force 3,750 kN, inclination in the standard case ± 8.5°, length up to 38 m (including 8 m bond length). The anchors are designed as permanent anchors of Class 6 according to SIA standard 191. Free movement was not necessary and indeed from the aspect of static behaviour was not desirable. The free tendon length therefore was grouted without overpressure after stressing. For permanent monitoring, a proportion of the anchors were constructed as surveillance anchors.

Construction took place form 1979 to 1981. A total of 110 VSL rock anchors were installed.

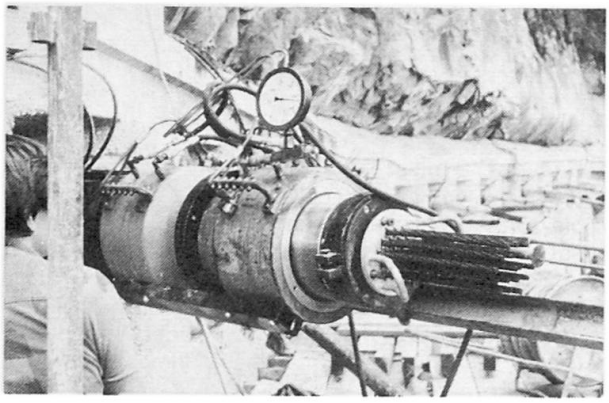

Fig. 2 Stressing an anchor of the rock fall gallery N2 Lopper

Gallery «Les Grands Rochers»

In the course of extending the Cantonal Highway, the rock was cut back here to a height of about 20 m and secured with VSL-/SIF-TMD rock anchors 5-11 (working force 1,100 kN, test force 1,540 kN). The existing protection gallery beneath was then lengthened by 191.50 m and that above by 45.50 m.

The structure of the new sections consists of the roof, with an outward downward slope of 15° and comprising prefabricated T-beams spaced at 6 m centres and prefabricated deck slabs of 200 mm thickness, and of the prefabricated struts, inclined inwards towards the rock at 10°. The structure was designed for a force of 100 kN/m acting upon its outer edge. The design was checked by means of a model in concrete. As a result of the use of prefabrication, the traffic in the region of the site was only slightly disturbed.

Each of the upper T-beams is anchored by two VSL-/SIF-TMD rock anchors 5-18 (working froce 1,800 kN, test force 2,520 kN, inclination +20°). The anchors are from 12 to 18 m long. In the free length, the strands are individually greased and polyethylene-sheathed (monostrand type). To the left and right of each T-beam, external prestressing tendons forming an extension of the anchors and coupled to them continue to the front end of the beam, where they are anchored. These tendons act as inclined cables for accepting the dynamic forces.

This gallery was constructed in 1978/79.

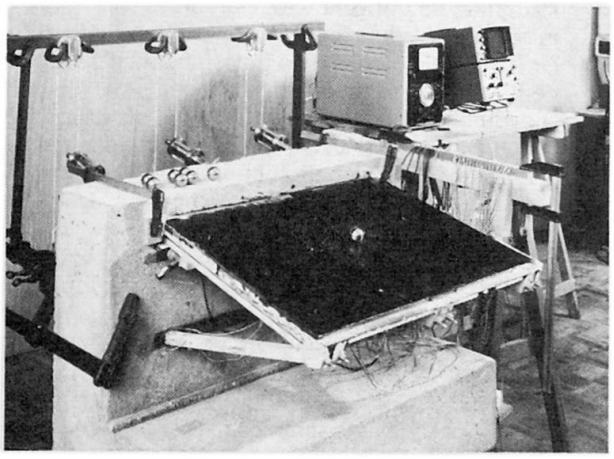

Fig. 3 Model test for the gallery «Les Grands Rochers»

Rock fall and avalanche gallery «Fehdenwald»

The Sustenpass-Strasse war protected by a gallery in the Wassen-Husen section following the Leggistein tunnel. In the first construction step (1979), a section approximately 45 m long was built. In 1983/84, a further length of approximately 642 m was added, of which a section of about 170 m is anchored in the rock with post-tensioned anchors.

The gallery consists of a cover slab, which in the standard cross-section is 450 to 650 mm thick and is supported at the uphill side by concrete ribs, generally 800 mm wide and at an average spacing of 8 m, while on the downhill side it rests upon circular solid steel columns Ø 240 mm, at 4 m spacing. The slab has a joint with meshing teeth every 24 m and a reinforcement on each side in the form of a 600 mm wide, 370 mm deep over-beam. Each over-beam is anchored with a post-tensioned rock anchor VSL Type E_F 5-12 (working force 1,050 kN, test force 1,470 kN). Other anchors were positioned in the region of the support ribs, while at 600 mm from each anchor a bearing plate with an empty duct was located, to provide the possibility of replacing a possibly failed anchor with a new one, as specified by the SIA standard 191 for anchors of Class 6.

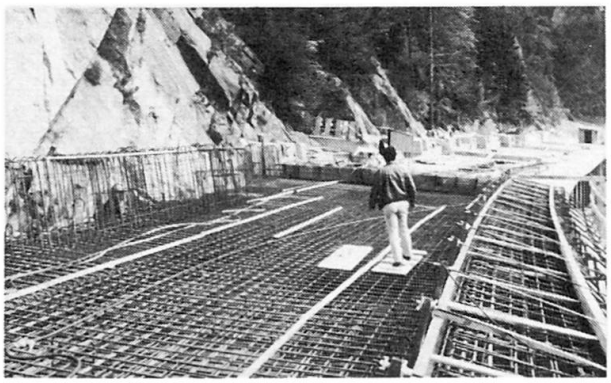

Fig. 4 The roof of the «Fehdenwald» gallery under construction

The gallery was designed for the following loads:
- Permanend loads, that is self-weight, insulation and fill
- Live load of 5 kN/m² from snow and debris
- Rock fall from a rock of 10 m³ volume striking at a velocity of 10 m/s at an angle of 35°
  For this loading case, increased admissible stresses were permitted.

The fully corrosion-protected, permanent anchors slope downwards at approximately 6°. They have a free length of 11 to 13 m and a bond length of 6 m. The anchors resist the horizontal forces from the frame action of the structure and from the rock fall and avalanche tension. In total, 47 anchors were installed.

(H. U. Aeberhard)