REHABILITATION MEASURES OF A ROCK-FALL GALLERY

"GALLENSCHROFEN", DISTRICT INNSBRUCK LAND, AUSTRIA

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INTRODUCTION

In spring 2010, remarkable movements were recognized on the rock-fall gallery "Gallenschrofen". This gallery was built in 1997 and is situated in the Tyrolean district Innsbruck Land in the community of Navis. A typical cross-section of the gallery is represented in Fig. 1. A detailed inspection of the complete building revealed that two of a total of 19 anchors were broken. A failure of the entire gallery could not be ruled out, especially in case of a rock-fall event.
Due to an intensive geological and geotechnical investigation program the reconstruction works on the rock-fall gallery were initiated. Those investigations were executed by the Austrian Federal Service for Torrent, Avalanche and Erosion Control in the years 2010 and 2011. The following paper aims at an analysis of the reasons for the failure of the anchors.

GEOLOGICAL AND GEOTECHNICAL INVESTIGATIONS

Detailed geological investigations were conducted by the Geological Service of the Austrian Torrent and Avalanche Control based on field works and two rock-fall simulation profiles. The first theory that rock pressure from the fractured carbonate rock present on the slope caused the failure of the anchors was rebutted by the field work.
Immediately, a monitoring system, the so-called "MOSES" (**Mo**bile **S**ecurity **E**mergency **S**ystem), was installed, whereby the fission cracks in the concrete of the construction building was measured constantly by crack-meters with remote data transmission via GSM net. Furthermore, all anchors were subject to pull-out tests where they were pulled with 50% of the breaking force of the steel-rod. The pull-out tests showed that the anchors were under considerably higher stress (up to 950 kN) than pre-stressed initially during the construction of the gallery (600 kN).
The geotechnical investigation elaborated on the results of the geological analysis, including the rock-fall simulations and the analysis of the measurements provided by crack-meters of the MOSES device. In a first step, the stability of the construction itself was recalculated, taking into account methods representing the actual state of the art. The results of the geotechnical investigation and recalculation of the construction showed that the stability of the gallery could only be guaranteed in the case of intact anchors, which were pre-stressed up to 600 kN in the year 1997. In case of a rock-fall event, the complete gallery could tilt over and the still existing anchors (D+W 1080/1230) could break.

ERROR ANALYSIS

Consequently, to avoid similar failures in the future and to design measures providing stable conditions for the gallery, the reason for the failure was analysed. The following factors provided the basis for the investigation:

- the position of the faulty anchors,
- the forces acting on the anchors that were still intact,
- the geometry of the cracks in the concrete structure of the gallery,
- the effect of the partial removal of the damping cushion on the roof of the gallery on the opening of the fissures,

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- the results of a investigative trench excavated at the foundation of the gallery and a
- structural calculation: chosen earth pressure and soil loading (assuming solid rock)

The picture drawn by those variables led to the conclusion, that the soil representing the base-plane of the foundation could not handle the pressure acting on the sandy gravel present instead of rock. Presumably, the structural calculation was based on too low earth pressure and a too high load bearing capacity of the underground. Additionally, the presence of subsurface and partly groundwater (melting and freezing) behind the gallery represent another unfavourable influence on the construction not considered sufficiently at the structural calculation.

RECONSTRUCTION MEASUREMENTS ON THE GALLERY

Therefore, the most reasonable and economically remedial measure was to reinforce the existing and replace the failed anchors. By regarding the results of the investigations, the consequences of the rehabilitation measurements on the rock-fall gallery were to stabilize the projecting slabs by nine anchored and pre-loaded concrete tie beams. These stabilization measurements were necessary to absorb the static equivalent load of 985 kN and 634 kN respectively for two different slope sections derived from rock-fall simulation. The calculation of the static equivalent load from the kinetic energy was conducted using the Swiss approach described in BAS (2008). In addition, the surface run-off being collected on the top of the gallery as well as water arriving from subsurface are now harmlessly discharged by a new drainage-system.

PREVIEW AND CONCLUSION

The drainage measurements were completed in the year 2010 and the completion of the construction work will be finished in spring 2011. The analysis of the failure shows – not very surprisingly – that the conception phase of mitigation measures is of utmost importance. Various different mitigation concepts should be considered in this stage, with special emphasis on efficiency and expediency.
In this case, the selection of the specific rock-fall gallery-type was not the best practice. A realignment of the road to be protected or a gallery being supported by concrete piles valley side, would have been a better choice in retrospect. Therefore, the reconstruction works are very complicated and hence expensive from a geotechnical point of view.

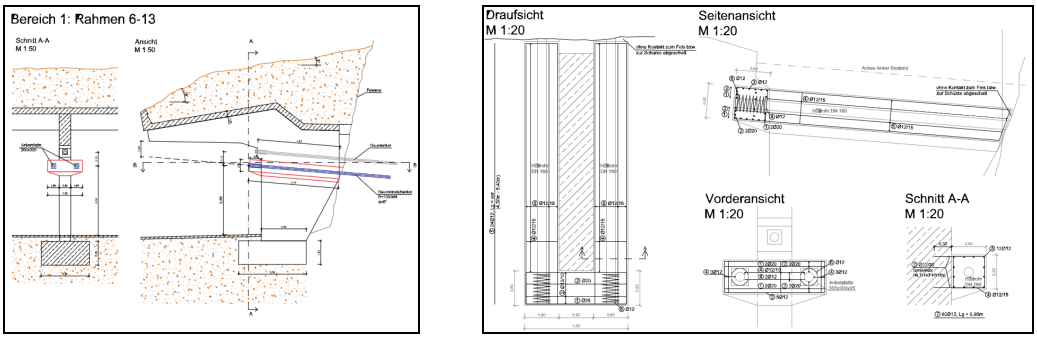

Fig. 1 Stabilization of the projecting slabs by 9 anchored and pre-loaded concrete tie beams

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