Innovative high capacity anchors to secure a motorway in Austria

Des tirants d'ancrage de grande capacité pour la mise en sécurité d'une autoroute en Autriche

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ABSTRACT

More than twenty years after the completion, the motorway A2 from Vienna to Graz still has to be monitored due to possible landslides in a mountainous area. Existing anchors were overloaded and the required additional anchor force could hardly be transferred to the non homogeneous rock within a drilling length of 100 m. The limited space between existing anchors determined very sharp criteria regarding borehole deviation. Works had to be executed on a very steep slope considering the existing concrete beams. Single bore multiple anchors allowed to reduce the number of anchors and their length. They could be tested successfully up to a single anchor load of 5.700 kN!

RÉSUMÉ

Plus de vingt ans après sa construction, l'autoroute A2 de Vienne à Graz demeure sous surveillance continue vis-à-vis des glissements de terrain dans une zone montagneuse. Les tirants existants étaient sollicités au-delà de leur capacité, et le transfert des efforts supplémentaires dans le rocher hétérogène était à peine réalisable avec des forages se moins de 100 m de profondeur. Le maillage serré des tirants existants imposait des critères très stricts quant à la déviation maximale des forages additionnels. Les travaux étaient à réaliser le long d'une pente très raide et en prenant en compte les poutres existantes en béton armé. L'utilisation de la technologie SBMA (tirant à torons multiples dans le même forage) a permis de réduire le nombre et la longueur des tirants additionnels. Les essais de résistance à la traction sur un tirant ont permis de le charger avec succès jusqu'à 5.700 kN!

Keywords: landslide, single bore multiple anchors, high capacity anchors

1 INTRODUCTION

The motorway A2 was constructed between 1983 and 1985 connecting Vienna to the south of Austria. It became one of the busiest highways in that area when the opening of Eastern Europe multiplied the traffic to Italy and former Yugoslavia. The 377 km long motorway crosses the foothills of the European Alps between Vienna and Graz in a zone, where the geological situation provides several difficulties to the cutting of slopes or building of embankments. Therefore some stretches of the alignment required further attention even after completion of the construction.

"Degendamm" is an embankment on a steep slope that could not be stabilized through the retaining measures applied in two phases. It became an emergency case when deformations were continuing representing a serious threat to the safety of the motorway. But the situation was not favourable to a quick intervention:

- Restricted space due to existing retaining elements
- Limited access due to the steepness of the slope (>40°)
- Time necessary to get an effect from additional retaining measures involving large quantities of anchors (works had to be interrupted during the winter season because of the snow in this area)
- Limitation of next steps due to the budgeting situation

Although there was no doubt that works had to start as fast as possible, it was not easy to define the best way to overcome the unfavourable conditions. The safe tunnel solution (deviating the problematic embankment) was sorted out because of the time required to get such solution operational.

2 THE PROJECT

2.1 *Chronology of the construction, geology*

A 30 km stretch of the A2 ("Wechselabschnitt") provided particular challenges already during construction due to the geological and topographical conditions (Fig.1).

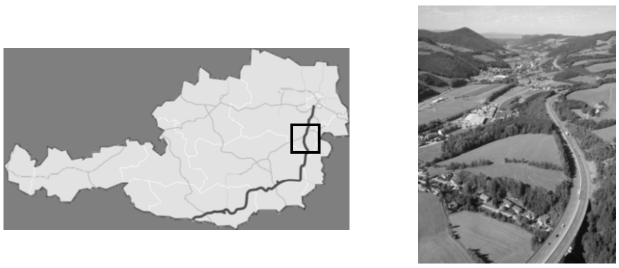

Fig. 1. Motorway A2 in a map of Austria; aerial view of the "Wechselabschnitt"

The mountainous area is characterised by fine grained upper layers forming instable slopes even at moderate inclination (thickness up to 30 m). The ongoing problems in some zones are related to very heterogeneous hard soil/soft rock – conditions below this layer that can reach important depth (> 50 m). Time – related phenomenon's of the material properties sometimes turn engineers judgement difficult. Degendamm is situated in one of these points where competent rock could not be found at reasonable depth.

2.2 *Observational approach*

The original construction of the motorway stood under considerable financial pressure. Therefore the observational approach was agreed between government and design consultants. Well aware that later interventions could be necessary, a relative minimum of retaining measures was used

Proceedings of the 17th International Conference on Soil Mechanics and Geotechnical Engineering
M. Hamza et al. (Eds.)

doi:10.3233/978-1-60750-031-5-2585

in order to stabilise only the most critical slopes. An extensive monitoring scheme (inclinometers, topographic survey, anchor load control, etc.) was installed and maintained over the years. Summarising the experience with this approach it becomes evident, that there is still a financial saving compared to a 100% solution from the beginning that would comprise many superfluous works. Considering the results of the frequent monitoring the safe use of the motorway was never interrupted.

2.3 *Stabilisation measures*

When first movements below the Degendamm embankment appeared 1985, a first anchoring campaign was executed before the opening of the motorway (Fig.2):

- 420 nr. of permanent anchors
- Length 50 m
- 1.000 kN working load each
- Installation of extensive monitoring (inclinometers, extensometers, geodetic survey)

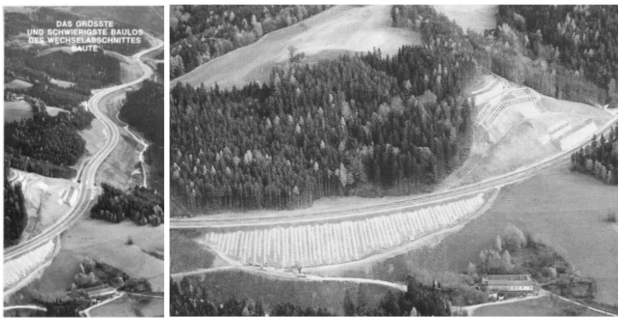

Fig..2. Situation after first phase of anchor installation 1985

After the regular checking of the ongoing deformation in 1992, the anchor load was increased to 1,2 of the design load. But slow sliding never stopped completely and the anchor loads showed a further increase. The base of the sliding mass was now detected below the level of the existing anchors. Large reinforced concrete piles were installed 2003 in order to stabilise the base of the slope:

- ~ 19 elements
- 6,4 m diameter
- 55 m depth

The location of these piles was not only given by the contour of the sliding mass but also by the access for heavy construction equipment (Fig. 3).

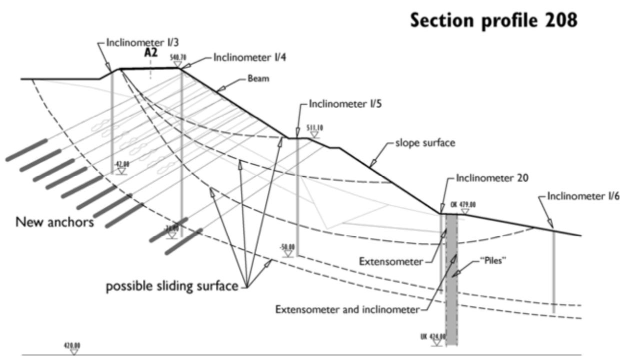

Fig. 3. Typical cross section

2.4 *Recent development*

Although considerable effort had been spent to increase the safety factor of the slope in a selected way, sliding continued after short time (after completion of these works the rate of 41 to 68 mm per year was reduced but still in a range of 16 to 48 mm every year). The instruments placed in the new large piles indicated a deeper sliding surface comprising the anchored body. At that time, existing anchors were already overloaded by 40%, some anchor heads destroyed or threatened by corrosion. At this point emergency measures were recommended by the geotechnical consultant.

3 PUBLIC PROJECT REQUIREMENTS

3.1 *Boundary conditions*

It was evident that various problems had to be solved in order to install effective retaining force:

- Risk to damage existing (overloaded) anchors when drilling additional anchors
- Risk to damage existing anchor beams when additional beams would cause deformation in the ground during tensioning procedures
- Risk to loose up to 125 m long boreholes due to drilling problems in the heterogeneous soil
- Risk to transfer the high design load of 1.900 kN of the new anchors to the weak mylonitic rock in the bonded length (with no geometric alternative for additional anchors)
- Risk to provoke further movement due to drilling impact or grout pressure resulting in an immediate interruption of the traffic

3.2 *Budget versus public procurement policies*

Specifications of the public tender considered the above listed requirements. The price for more than 400 anchors with a length up to 125 m and a working load of 1.900 kN (Fig.4)each was extremely high, because guided drilling had to be involved in order to overcome the problems due to expected drilling deviation (serious deviation was observed during the execution of a trial). Thus exceeding of the available budget at that time became the last threat of the project being already under extreme time pressure.

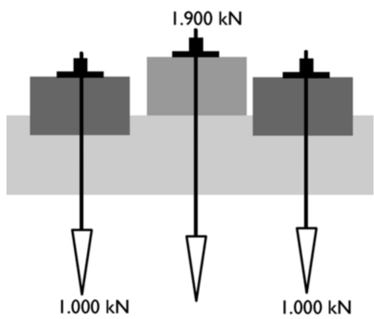

Fig. 4. First design of position of new beams

In this phase an alternative solution proposed by the Keller Group was considered the only way to provide a proper solution to the problem:

- Reduction of the number of elements using considerably higher anchor forces (doubling the allowable drilling deviation)
- Reduction of the maximum anchor length using the SBMA principle (Fig.5 and Fig.6)

- The shorter bonded length of new anchors was still situated behind the lowest sliding surface updated according to actual measurement
- Measurement of the drilling deviation at all anchors
- Width of the new anchor beams was spread in order to involve the existing beams resulting in a reduction of the load of existing anchors. (Fig.7)
- All described steps allowed to optimise the working programme and contributed to a faster gaining of additional safety.

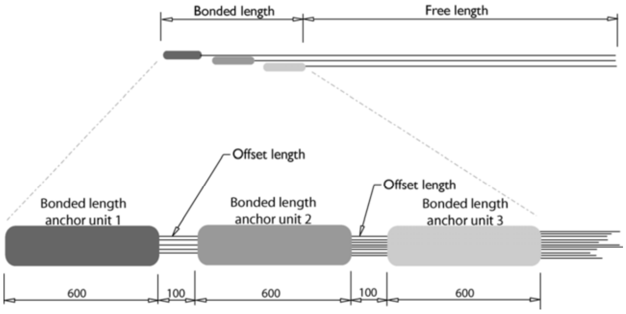

Fig. 5. Principle function of Single Bore Multiple Anchors

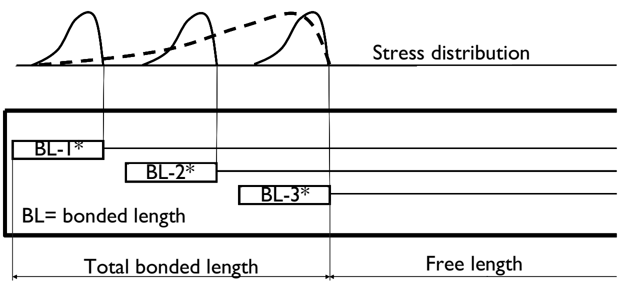

Fig. 6. Schematic function of a Single Bore Multiple Anchor

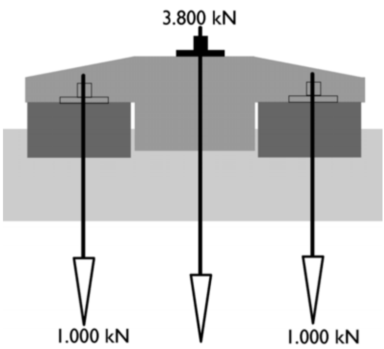

Fig. 7. Alternative design of high capacity anchors

4 SITE ORGANISATION

After all involved experts had approved the alternative design - approach, a trial had to verify the feasibility of the optimisation potential.

The challenge was nothing less than to install an anchor for 5.700 kN load to be reached in a precisely described sequence during the qualification test!

Several elements of the new anchor system had to be developed in short time such as:

- Anchor head scheme with three separate anchors (six strands each but with different free length)
- Automatic registration system for three different anchors to be tensioned at the same time
- Improved PVC coating
- Sophisticated post – grouting system in order to become more independent from local weak zones in the ground suing grout based on CEM 42,5R
- Combined water – air – flash for 85 m long boreholes in order to minimise the impact to the soil (Fig.8)

Fig. 8. Drilling situation and used tools

All acceptance tests were executed according to the load steps described in EN 1537. Additionally every strand was tested separately up to a single load of 167 kN (Fig. 9).

Fig. 9. Stressing the Anchors

Load steps were maintained for 1 hour. The anchor head was specially designed with distance rings to allow the later release if necessary.

4.1 *Access for anchoring*

A powerful drilling rig had to be assembled for this project, able to work at the maximum inclination of almost 45° (rubber tracks, empowered erection mast support, enhanced rotary heads).Safety was provided in all phases using radio – controlled winches and mobile cranes for all manipulation steps. A modular setup was developed which comprised separate mobile platforms for drilling equipment, monitoring, operation and data registration to be moved by 100 ton mobile cranes. (Fig.10 and Fig.11)

Fig.10. Assembly and installation of anchors

Fig. 11. Steps to move the rig to the drilling position

4.2 *Time of execution*

The optimisation of the quality against the quantity specified in the tender resulted in a significant saving of time. It is important to mention, that the stabilisation of the ongoing deformation of the slope could be reached much earlier this way.

4.3 *Technical and organisational alternatives*

While the horizontal deviation of the boreholes could be maintained within 0.4% of the drilling length, vertical deviation was much higher (measured at each element with a Maxibor device). Fortunately the deviation was generally to the low and therefore the necessary distance between neighboured anchors was always maintained.

5 RESULTS

More than 200 anchors with a working load of 3.800 kN could be installed regularly in the years 2008 and 2009 (Fig.12). Full stabilisation of the slope was reached in this period. Anchor loads could be reached in soft and weak rock conditions using the Single Bore Multiple Anchor method combined with new elements like high resistance strands, high quality wedges and pressure resistant post grouting devices.

Fig. 12. Actual view of the site

6 CONCLUSION

The European Standards as well as national regulations hardly reflect such project – related solutions. But exactly these technical and organisational challenges provide the opportunity for relevant innovation. In this case the public owner took the risk to fail and was fortunate enough to get the positive result of the effort spent between designers, geotechnical experts and specialised contractors.

ACKNOWLEDGEMENTS

The author is grateful to Prof. Heinz Brandl for supporting an approach that exceeded most of the existing anchoring experiences. Thanks should be given to the responsible persons of ASFINAG motorway authority, the technical department of the country Lower Austria, design engineers Blovsky, Öhlinger and Lechner and contractor Massivbau.

REFERENCES

All project information was taken from the tender documents, details of execution were taken from Keller Grundbau’s site report.