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Flexible high modulus geogrids used as tie-back anchors for retaining structures

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ABSTRACT: Two different case studies are presented in this paper, dealing with the application of flexible, high modulus geogrids used as temporary tie-back anchors of vertical retaining structures.

The first case study deals with 10 m high temporary bridge, whereas the supporting I-beams are anchored with geogrids. The bridge was built over an existing road and railway in Switzerland to support a temporary construction haul road with heavy traffic. The I-beams were anchored at four different levels and a post-tensioning device for the geogrids was installed.

The second case study deals with a temporary anchoring of an existing sheet pile wall in Amersfoort, Netherlands. In course of infrastructural civil works the permanent anchors of a sheet pile wall had to be demolished. To guarantee the stability and to limit the deformation a temporary anchoring was needed. The use of conventional anchors was technically not feasible. The application of geogrids as anchoring element led to a cost-efficient, easy and quick solution, which was installed in less then two days.

1. INTRODUCTION

During civil works ground engineers are often confronted with difficulties which ask for special solutions. The wide range of different geosynthetic materials regarding raw material and technical properties often allow for innovative solutions. Developments in the past years in polymer technology have lead to the production of geosynthetic reinforcements produced from Polyvinyl Alcohol (PVA) and Aramid yarns, which exhibit a higher tensile modulus and lower creep propensity. PVA also offers an increased chemical resistance in pH extremes. But also “common” geosynthetics made from Polyester (PET) demonstrate to meet requirements for special solutions. Two cases studies are presented in this paper, where geogrids where used as temporary horizontal anchor elements of retaining strucutures. Depending on the deformation criteria and service life of the individual structures different raw materials were used.

2. CASE STUDIES

2.1. Temporary bridge abutment in Domat/Ems, Canton Graubünden (GR), Switzerland

An unusual solution for back-anchoring temporary abutments of a highly frequented bridge was applied for the first time in Domat/Ems, Switzerland.

To set-up a construction site for a large scale sawmill (Stallinger Swiss Timber AG) a provisional construction road, crossing an existing road and railway, was needed. To cross the existing road and railway a temporary bridge was constructed and operated for approximately six months in 2006. A total amount of 600.000 m^3 of excavated materials was transported over the bridge by dump trucks with a gross weight of up to 74 t, which corresponds to approximately 40.000 vehicles crossing.

The 10 m high two field bridge was supported in the middle. The span of each field was 11 m. The abutments of the bridge were designed as soldier beam walls (aka Berlin type pit lining). The soldier beam walls of each abutment was back-anchored by four layers of a high- strength Fortrac® geogrid, figure 1.

The connection detail of the geogrids to the soldier beam walls resp. to the I-beams was developed by the engineering company in charge by help of a former, similar project served by Schoellkopf AG.

The back-anchoring of soldier beam walls supporting a bridge on top by four layers of geogrids was a real novelty in Switzerland. Before that, only the execution of one permanently secured, back-anchored sheet pile wall was known in Switzerland.

Fig. 1 Temporary bridge with geogrids as anchor elements

The high-strength, low-creep Fortrac® geogrids used in this project are made from Polyester fibres. According to the design, the geogrids had to provide a design tensile strength of 150 respectively 220 kN/m.

Besides design and calculation, in particular constructive and installation related aspects became relevant.

How could the geogrids be connected to the I-beams? How could possible initial deformations be absorbed (pre-tensioning)? Which possibilities are given to apply forces afterwards (re-tensioning)? Considering this, beside all material related properties, especially the high flexibility of Fortrac® geogrids gained in importance. The described solutions would not have been feasible with rigid geosynthetic products, figure 2.

Fig 2. Refilling the first Fortrac® layer, the flexibility of the geogrid is important for a good connection

By means of a small trench a well dosed pre-tensioning of the geogrids was achieved. There have been only very little needs for re-tensioning. The geodetic and visual monitoring of the bridge and the two abutments showed horizontal and vertical deformations of less than 10 mm, whereas the maximum displacement of each abutment was about 5 mm.

Since it was a temporary bridge a great deal of attention was paid to the aspects of reusableness of all materials. Also the dismantling process should be as easy as possible. With the construction method chosen, the locally available resources could be used in the most economic way. All materials used in this project could be re-used at least once. The keynote of this project to build a technically, economically and ecologically optimised temporary bridge was successfully realized in all aspects by the applied construction method. Especially in conjunction with temporary objects, a construction which is back-anchored by geogrids represents a solution that is worth to be considered in every respect.

2.2 Temporary anchoring of a sheet pile wall in the city of Amersfoort, the Netherlands

The historical building „Het Spijkertje" had to be demolished in the course of a building project in the city of Amersfoort, the Netherlands. The reconstruction of the building at the same place next to a canal was planned for the future. Over the time the side protection of the canal was strengthened several times, so that the construction starting from the canal towards the building was as follows, figure 3:

- 12 m long sheet pile wall AZ 26, not anchored
- 8 m long sheet pile wall Larssen IIn, anchored
- old brick quay wall based on wooden piles

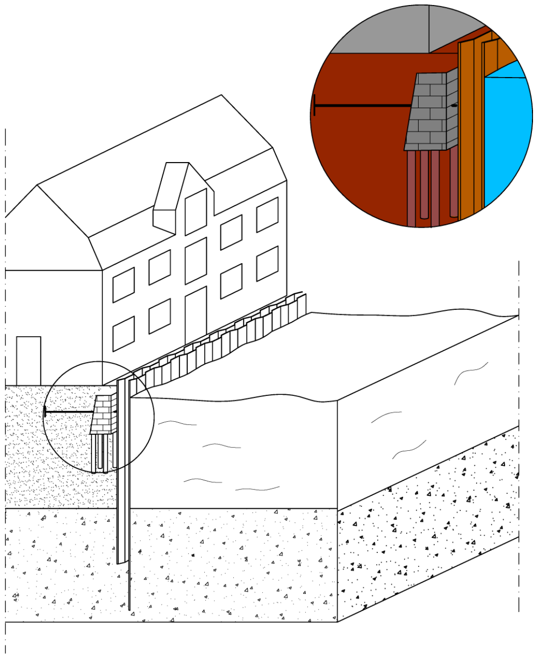

Fig.3 Encountered situation of the side protection of the canal

The old brick quay wall and the horizontal anchors of the 8 m long sheet pile wall had to be removed over a length of about 22 m, since the "Het Spijkertje" will be reconstructed with a basement. It was not clear at this stage of the project, when the reconstruction would take place. Meanwhile the space should be used as a material storage and working area. Therefore soil had to be brought in to a certain level in front of the sheet pile wall after removing the old quay wall and anchors. A suitable anchoring system was required to guarantee the stability and limit deformation to less then 10 mm.

The contractor took different solutions into account:

- *Horizontal anchors* - Due to the future basement a horizontal anchoring of the sheet pile wall below the building was not feasible.
- *Two anchors on either side of the basement* - It was considered to use only two anchors on either side of the new basement. The load induced by the sheet pile wall over a length of about 22 m should have been transferred via cross beam into the two anchors. This would have led to unrealistic beam sizes and would have produced extreme anchor forces of about 935 kN. Due to economical reasons, this solution was rejected.
- *Inclined anchors* - Another option was to incline the anchors, in order to pass below the basement. The required inclination would have been large, since the sheet pile wall was close to the new basement. This increases the anchor forces on one hand and would result in higher vertical loads to be born by the sheet piles. Concerns were raised, that the vertical loading capacity of the sheet pile wall would be exceeded.
- *Installing a third sheet pile wall* - A third not anchored heavy sheet pile wall with a length of about 14 m in front of the 8 m long sheet pile wall was considered. Again this idea was rejected due to economical reasons.
- *Coupling the two existing sheet pile walls* – A further concept was developed in which concrete was filled between the existing sheet pile walls to connect them and to produce a stiff quay wall. The solution was not chosen due the uncertainties with regard to the actual stress distribution and deformations during the compaction of the concrete.
- *Connect the sheet pile wall onto the basement* - The connection between the sheet piles and the basement was not possible due to the non existence of the basement.

After evaluating all different possibilities, a permanent solution appeared to be too expensive and could not eliminate certain risks.

As a solution the installation of a temporary anchor system was chosen before connecting the sheet pile wall later onto the new basement. The temporary anchor system was executed by using a flexible, high tensile and very stiff geogrid made of PVA, a Fortrac® 600/50-30 MP. Due to its flexibility the connection between the sheet pile wall and the geogrid was relatively easy to construct. U-shaped steel rings were welded onto the sheet pile wall for the connection. In the next step the geogrid was placed close to the sheet pile wall and a steel pipe was pushed through the rings, figure 4.

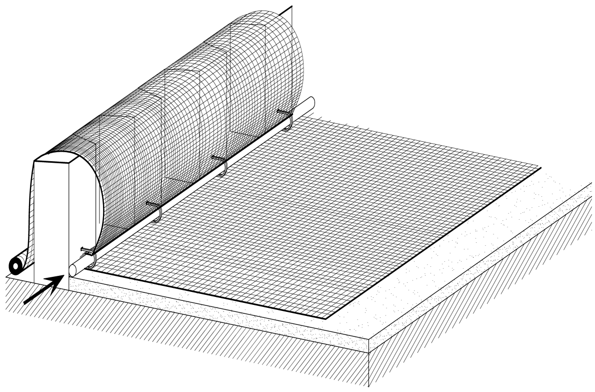

Fig.4 Connection detail – a steel pipe is pushed through the rings to connect the geogrid with the sheet pile wall

A sand layer was placed and compacted over the placed geogrid layer. Afterwards the remaining geogrid was wrapped back over the steel pipe, so that at the end two layers of the geogrid were placed. The upper layer had an extra length of about 0,5 m with no static use. The reason for this extra length was to facilitate the prestressing of the geogrid by simply grapping and pulling it with the shovel of an excavator, figure 5.

Fig.5 Pretensioning the geogrid by placing a bulg of earth at the and then pulling it with the excavator shovel

By placing a bulg of soil onto the geogrid at the end, the tension was kept. After that the backfill started from the end towards the sheet pile wall up to a certain distance, where a small trench was installed below the upper layer of the geogrid. By placing soil onto the geogrid, the grid got pushed down into the trench and a further tensioning was achieved, figure 6.

Fig. 6 Connection detail and the tensioned geogrid

The temporary anchor system with Fortrac 600/50-30 M was installed in only two days and no deformation of the sheet pile wall was noticeable. The use of a flexible Fortrac geogrid made of PVA led to a cost- effective, easy to install and successful solution for this project.

3. SUMMARY

The paper presented two different projects, where special anchoring solutions due to the particular circumstances were required. After evaluation of different conventional solutions the use of geogrids as horizontal anchor elements for the described retaining structures proved to be the best solution under the given boundary conditions. Measurements resp. observations demonstrated non or very small deformations, which were all within the required limits. Back-anchoring retaining walls with flexible geogrids allow for cost-efficient, simple and successful innovative solutions.