# INNOVATIVE APPLICATIONS OF GEOGRIDS AS TIE-BACK ANCHORS FOR VERTICAL WALLS

**Oliver Detert[1], Edi Wehrli[2] & AlexanderCejka[3]**

[1] *Huesker Synthetic GmbH. (e-mail: detert@huesker.de)*
[2] *Schoellkopf AG, Switzerland. (e-mail: wehrli@schoellkopf.ch)*
[3] *Josef Möbius Bau-Aktiengesellschaft. (e-mail: alexander.cejka@moebiusbau.de)*

**Abstract:** This paper describes three different projects, where the application of flexible, high modulus geogrids proved to be the best solution.

First case: An additional anchoring of an existing sheet pile wall was necessary in Amersfoort, the Netherlands, due to an increase of loading. The use of conventional anchors was technically not feasible. The installation of a geogrid anchoring was a cost-efficient, quick and easy solution, which was installed in less then two days. To keep the deformation of the sheet pile wall to less than 100mm a high modulus geogrid made of Polyvinyl alcohol was used.

Second case: A temporary, 10 m high bridge had to be built over an existing road and railway in Switzerland to support a temporary haul road with heavy construction traffic. The abutments were constructed using a series of I-beams with open timber polling's. Anchorage of the I-beams was carried out at four different levels using a geogrid from high tenacity polyester. A technical solution for post-tensioning the geogrids after the construction of the abutments to limit the face movements was installed.

Third case: During the construction works of the motorway BAB A20 close to Rostock very bad soil conditions were encountered due to the presence of an infilled lagoon. The soil exhibited very low undrained shear strength (<5 kPa) to a depth of 15 m. The motorway to be built in this section was on an embankment up to 15 m high. A change of the road alignment was not possible. The final solution consisted of slope support combining two rows of 21 m long steel tubes vibrated into the ground as a vertical supporting wall, horizontally anchored by, up to, 28 m long Aramid geogrids.

**Keywords:** anchor, bridge abutment, geogrid reinforcement, geotechnical engineering, innovative technologies, retaining structures

## INTRODUCTION

Often geotechnical engineers are faced with difficulties which need special solutions. The wide range of geosynthetic materials with variable strength, different raw material and other 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 than other common polymers. PVA also offers an increased chemical resistance in extreme pH conditions. Some “common” geosynthetics made from Polyester (PET) demonstrate properties for special solutions. In this paper three innovative applications are presented, where geogrids are used as temporary and permanent horizontal anchors of retaining structures, normally anchored with steel anchors. Depending on the deformation criteria and service life of the individual structures different raw materials were used.

## CASE STUDIES

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

During a building project in the city of Amersfoort, the Netherlands, a historical building called “Het Spijkertje” had to be demolished. A reconstruction of the building at the same place next to a canal is planned for the future. Historically the side protection of the canal has been strengthened several times, so that the construction starting from the canal towards the building as follows, Figure 1:

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

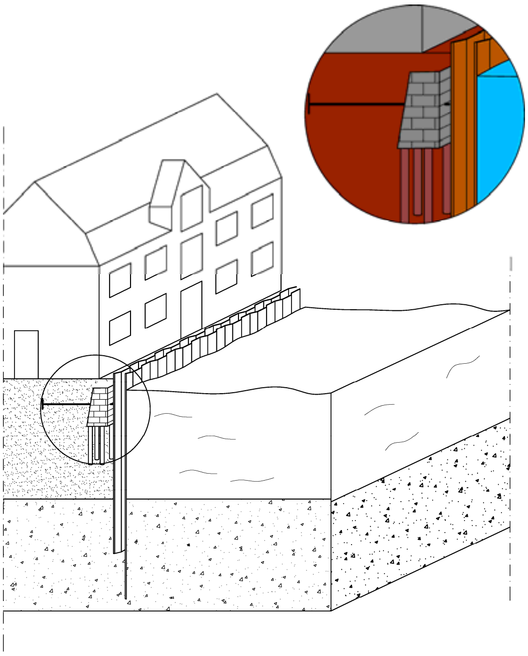

**Figure 1.** Encountered situation of the side protection of the canal (graphic: Huesker)

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. At this time it was not clear, when the reconstruction would take place. Meanwhile the space would be used as a material storage and working area. Therefore the soil level in front of the sheet pile wall needed to be raised after removing the old quay wall and anchors. To guarantee the stability and limit deformation to less then 10 mm a suitable anchoring system was required.

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 required very large and unrealistic beam sizes and would need 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. The inclination increases the anchor forces and would results 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 cantilvered 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 on economical grounds.
- *Coupling the two existing sheet pile walls* – A further concept was developed in which concrete would be placed 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 new basement was not possible as the basement was ye to be constructed.

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

As a solution the installation of a temporary anchor system was chosen, before connecting the sheet pile wall to the new basement at some time in the future. The temporary anchor system was executed by using a flexible, high tensile and very stiff geogrid made of PVA, (Fortrac® 600/50-30 MP). The flexibility of the connection between the sheet pile wall and the geogrid was relatively easy to construct. The connection consists of u-shaped steel rings, welded onto the sheet pile wall. In the next step the geogrid was placed close to the sheet pile wall and a steel pipe was pushed through the rings, Figure 2.

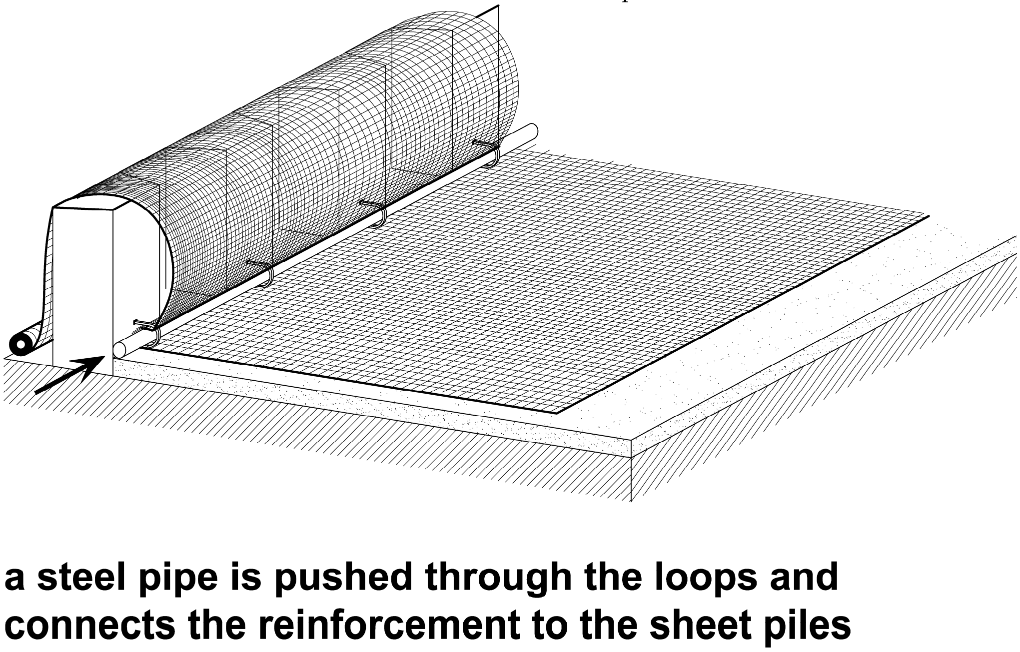

**Figure 2.** Connection detail (graphic: Huesker)

A sand layer was placed and compacted over the first layer of the geogrid. Afterwards the 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 3.

**Figure 3.** Tensioning the geogrid with the shovel of an excavator (photo: Huesker)

By placing a bund of soil onto the geogrid at the end, the tension was kept.  The backfilling started from the end closest to the sheet pile wall up to a point, where a small trench was installed below the upper layer of the geogrid. By placing soil onto the geogrid, the grid was pushed down into the trench and a further tensioning was achieved, Figure 4.

**Figure 4.** Connection detail and the tensioned geogrid (photo: Huesker)

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

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

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

In the course of preparing a construction site for a large sawmill (Stallinger Swiss Timber AG) in Domat/Ems, a temporary construction road had to be established leading over a temporary bridge. The bridge was to be used for approximately six months from June 2006, by articulated dump trucks with a gross weight of up to 75t. A total amount of 600.000 $m^3$ of excavated material was transported over the bridge, which corresponds to approximately 40.000 vehicles crossing.

The 10 m high bridge consists out of two spans, each 11 m wide, leading over a main road and two tracks of the Rhaetian Railway. The abutments of the bridge are designed as soldier beam walls (aka Berlin type pit lining). Each abutment is back-anchored by four layers of a high- strength geogrid, Figure 5.

**Figure 5**. Finalised bridge under traffic (photo: Schoellkopf)

The connection detail of the geogrids to the soldier beam walls resp. to the I-beams was developed by the designers following a similar project served by Schoellkopf AG.

At that time (2006), 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, single back-anchored sheet pile wall was known in Switzerland.

The high-strength, low-creep geogrids used in this project are made from polyester fibres. Taking into account the reduction factors A1 for creep and A2 for installation damages, the geogrids had to provide a design strength of 150 respectively 220 kN/m.

In addition to design and calculations, construction and installation related aspects were important. How could the geogrids be connected to the I-beams? How could possible initial deformations be absorbed (pre-tensioning)? How could the geogrid be tensioned in service (re-tensioning)? Considering these aspects, and the material related properties, especially the high flexibility of the polyester geogrid was important. The above described solutions would not have been feasible with a stiff geosynthetic product, Figure 6.


**Figure 6.** Refilling the first Fortrac® layer, the flexibility of the geogrid is important for a good connection (photo: Schoellkopf)

The easy to apply pre-tension force, which was applied using the pre-tensioning trench, has resulted in very little need 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.

During the planning phase close attention was paid to the aspects of the reusability of all materials, since it was a temporary bridge. The dismantling process was to 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 construction methods selected. 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.

**Autobahn A 20 – Permanent anchoring with geogrid made of Aramid**

During the construction of the new Autobahn A20, the so called Baltic Sea motorway, very poor soil conditions were encountered in a section over a length of about 160 m between Sanitz and Tessin. In this section a 15 m high road embankment was to be built on extremely soft soil, with a thickness of about 15 m and very low shear strength. Due to time constraints a change of the road alignment was not possible. Different construction methods were considered by the joint venture. A full soil exchange was not feasible due to the depth of about 15 m. The evaluation of other conventional solutions showed that as well as the difficult construction the cost would be extremely high. Additionally time and environmental considerations were dominating factors.

The solution developed included a slope stabilization concept, using a back anchored supporting structure, consisting of two rows of steel tubes, with a length of 21 m. The steel tubes were vibrated into the ground as a vertical supporting wall, horizontally anchored by a very high modulus flexible geogrid made of Aramid, (Fortrac® 400/50-30 AM). The two steel tube rows were installed with a spacing of twice the tube diameter. Geotextile encased sand columns (GEC) were placed between the steel tubes. To overcome the problem that the soft soil had a very low shear strength, the installation plant used the already installed steel tubes as a working platform, Figure 7.

**Figure 7.** Installation plant on the installed steel tubes (photo: Möbius)

The organic soil between the two rows was replaced by installing sand columns using the displacement method. The upper ends of the steel tubes were connected by a special steel construction and anchored with high modulus geogrids with a length of about 28 m, which were placed plane and without any folding but not tensioned, Figure 8.

**Figure 8.** Placed geogrids connected to the two rows of steel tubes (photo: Möbius)

The remaining soft soil between the piles and the future road embankment was replaced with suitable material, Figure 9.

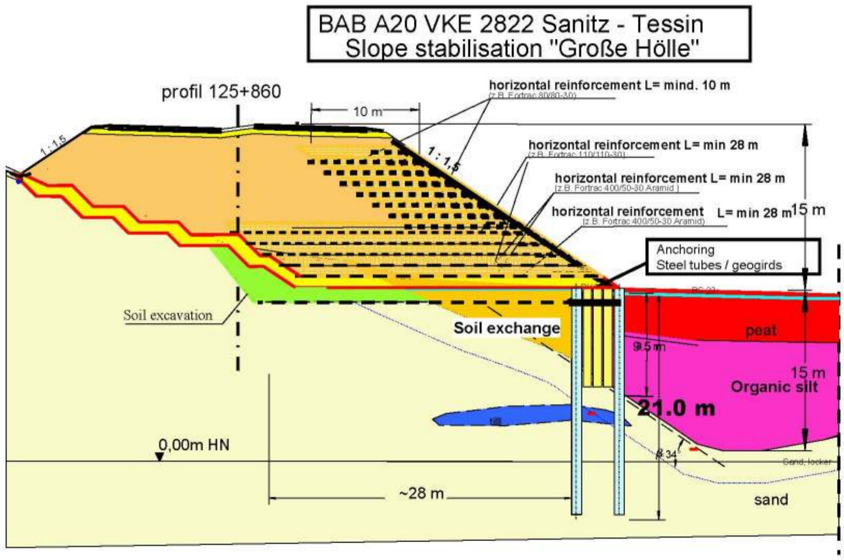


**Figure 9.** Profile of the stabilised embankment by means of steel tubes anchored with geogrids (graphic: Möbius)

The road embankment was constructed as a geotextile reinforced soil construction. The soft soil had virtually no horizontal resistance; the construction has to withstand a horizontal loading from about 30m of fill. The deformation measurements 8 months after the end of construction showed a horizontal deformation of only 5 cm, which is less then 0,5% of the embankment height, Figure 10.

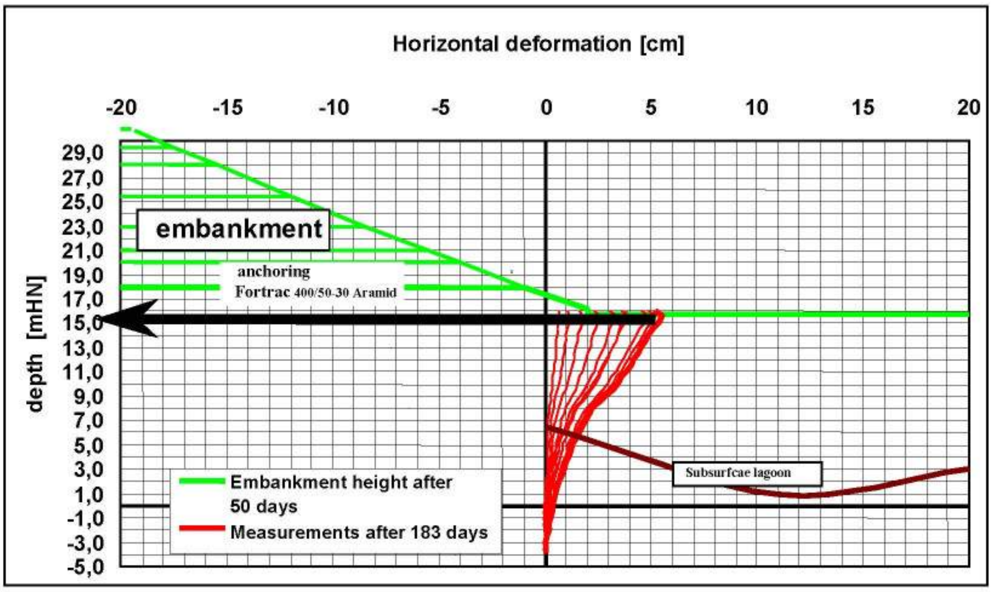


**Figure 10.** Horizontal deformation measurements of the geogrid anchored steel pipes for the slope stabilisation (graphic: Möbius)

This cost-efficient solution with geogrids made of Aramid as permanent anchors made it possible to finish the road construction successfully within time. Another advantage of using geogrids as an anchor element is, that no corrosion problem will occur.

## CONCLUSION

The paper presented three different projects, where special solutions due to the particular circumstances were required. After evaluation of different conventional solutions the use of geogrids as horizontal anchor elements for the retaining structures proved to be the best solution under the site specific conditions. Measurements and observations demonstrated very small or no deformations, which were all within the design limits. Back-anchoring retaining walls with flexible geogrids allowed cost-efficient, simple and successful innovative solutions to these problems.

**Corresponding author:** Mr Oliver Detert, Huesker Synthetic GmbH, Fabrikstrasse 13-15, Gescher, Nordrhein Westfalen, D-48712, Germany. Tel: ++49 2542 701 321. Email: detert@huesker.de.