Landmarks in Earth Reinforcement, Ochiai et al (eds),
© 2001 Swets & Zeitlinger, ISBN 90 2651 863 3

Construction of a geogrid-reinforced earth-wall inside a ware-house

François Viel
REHAU AG + CO, Erlangen, Germany

ABSTRACT: The construction of a new high-bay warehouse at REHAU's Viechtach factory in the Bavarian forest near the Czech border involved a major height difference (for incoming and outgoing goods) between the first and the second level (over 20 meters). Due to the undulating topography and limited space, retaining walls were essential to overcome the difference in levels. A 7.20-meter high geogrid-reinforced wall sloping at 85° was constructed 50 cm behind a facing concrete wall inside the warehouse. This way, no earth was expected to exert pressure against the concrete facing wall. As a second bonus, the reinforced concrete plate base for truck and fork-lift traffic at the second level on the geosynthetic wall structure was reduced in thickness

1 INTRODUCTION

The new construction of a warehouse in the existing REHAU factory of Viechtach in the Bavarian forest north east from Munich was needed to help the growing demand of goods transport and for logistic. Due to the limited space within the factory area and the level difference due to the topography, a high-bay warehouse was designed with 20 meters difference between the first level and the third level.. Owing to the nature of this project, a large volume of earth had to be removed, producing over 4,000 m³ of soil. Initially, detailed plans were drawn up to use reinforced concrete retaining walls. It seemed a good idea to use the soil as fill in a geogrid-reinforced earth-wall instead of dumping it. In total a second solution appeared more economical than the first one. REHAU decided to promote its own technology and use its polyester earth-reinforcing geogrids.

A 7.20 meter high geosynthetic retaining structure sloping at 85° including a 90° edge corner was constructed 50 cm behind a facing concrete wall inside the warehouse to prevent earth pressure against the face saving the construction of a consequent concrete retaining structure. The concrete plate on top of the geosynthetic structure at the second level, where truck and fork-lift are circulated, was reduced in thickness.

The very cramped conditions inside the warehouse and the 90° corner construction were really a big problem particularly for soil transport, installation and compaction during the construction. The soil was removed during the first summer and stored outside during the winter under rain and snow conditions. The construction inside the warehouse started on April of the second year.

Figure 1. Situation between the piles.

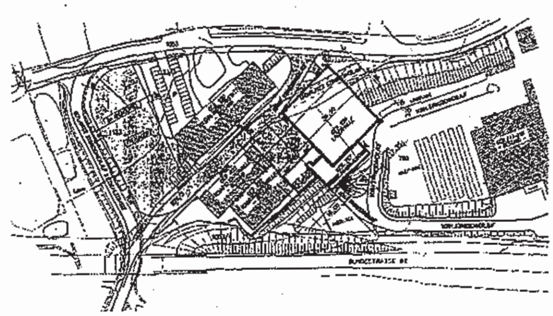

Figure 2. General situation within the factory with the new high-bay warehouse.

2 SOIL CONDITIONS

The first design included the use of the soil, the mechanical characteristics and the soil performance were tested in laboratory during the first year of the construction. To conserve these characteristics during the winter, it was decided to protect the stored soil against the weather conditions to allow a reutilization. The water content was measured between 8% and 10% (October 1998), the optimum water content was 11.5 %. After a hard winter and a lot of snow fall, the insufficient protection of the stored soil against rain and snow particularly during the snow melt in March, increased the water content till 15 % so that a reutilization was made uncertain.

To keep the project still attractive, it was necessary to find a soil alternative with the right capacity to be compacted and economic. The second soil alternative was found on the rubble of the Viechtach's quarry (silty sand) free of charge at about 4 km from the construction site. In that condition, the project was still economic and interesting, the soil characteristics were the followings:

- Density $\rho = 1{,}955$ g/cm³
- Optimum water content $W_{opt.} = 11{,}5\%$
- Friction angle $\varphi = 31{,}8°$
- Cohesion $c = 38$ kN/m²

The settlement over the reinforced geosynthetic-wall was calculated with 7 to 8 cm (about 1% of the total height of the wall). By starting the design, a supplementary provisory load during two weeks was planed on top of the geosynthetic wall to reduce the danger of settlement. Due to very short construction time, this was deleted. To prevent an overburden of stress and cracks due to settlements in the above installed concrete base plate, it was decided to improve the compaction till 103 % Proctor density. The optimum water content of the rubble was measured with 11,5% in laboratory to achieve this compaction grade. In the quarry, a quality-control was set up, only the rubble with the adequate water content was accepted. At the end of April, the water content on site was measured at 8 to 10 %, also sufficient to allow the utilization of the rubble. The whole construction is founded on the existing gneiss rocks with a compression resistance of 1.0 to 1.6 MN/m².

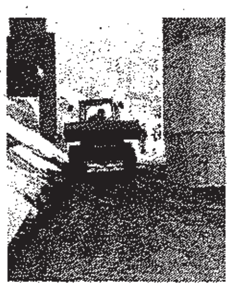

Figure 3. Soil transport between the piles.

Figure 4. Soil compaction in front.

3 STATICAL CALCULATION AND DESIGN

The geosynthetic-wall is considered statically to be a solid-wall as a retaining structure. The calculation is done with the two-wedge analysis and allows to determine the forces required for equilibrium, taking into account the geometry of the slope, the geotechnical properties of the soil, the pore water pressure and the surcharge loading. The calculation determines:

- the principal anchor length of the geogrid
- the spacing between the geogrid
- the geogrid strength
- the tie back length of the geogrid.

The geometrical dimensions within the warehouse are the following:

- Length of the geosynthetic-wall 48 meters
- Height of the cushion foundation 1.80 meters
- Cushion foundation with three geogrids layers, spacing 60 cm
- Height of the wall 7.20 meters
- Slope angle 85 °
- Reinforced wall with 14 geogrid layers, spacing 50 cm

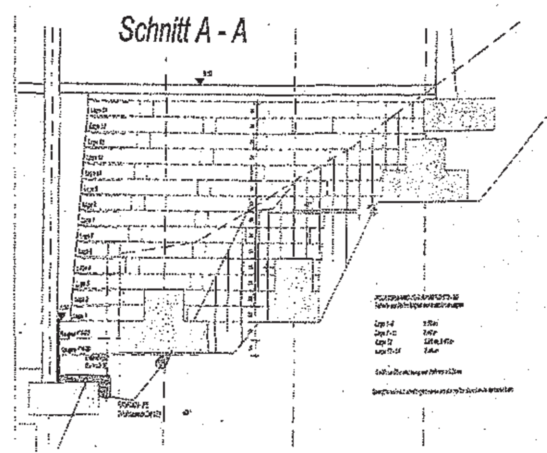

Figure 5. Cross section of the geogrid-reinforced wall.

The geogrids were installed horizontally with a tie back anchor on the front of the wall. The cushion foundation was necessary to achieve a good stability of the three pile-foundation during the construction before any supplementary loads (sideward support) could be applied.

The statical calculation has taken into account the following geogrid and factors:

- PET geogrid with 40 kN/m strength for the cushion foundation
- PET geogrid with 80 kN/m strength for the retaining structure
- Factors of safety:
  - Creep (120 years) 1.75
  - Mechanical damage 1.06
  - Biol. and chemical resistance 1.0
  - Calculation safety factor 1.75

The anchor length was calculated with 4.50 m by the first six geogrid layers (layer 1 to 6) and with 5.40 m by the last 8 geogrid layers (layer 7 to 14). The tie-back length was chosen with 1.50 m for all the geogrid layer. A drainage with a geocomposite on the rear of the wall was installed to collect possible ground water from snow melt behind the warehouse, the water is collected in a base drainage collector and transported outside the construction.

4 CONSTRUCTION OF THE WALL

The rubbles were transported direct from the quarry to the construction site and deposited on the foot of the construction outside the warehouse at the start of construction and unloaded inside the warehouse on the top of the construction at the end. For this purpose, the concrete facing panels of the warehouse were installed later and provisory ramps were set up.

The wall was built 50 cm behind a concrete facing wall, the wrap around was built with the help of a special movable formwork made of steel profiles. A steel plate was first installed horizontally every 2.0 meters on the previously constructed layer, secondly the movable part of the formwork was fixed

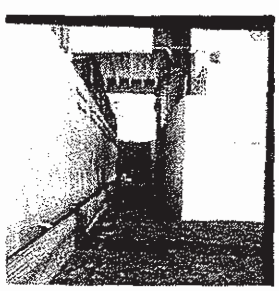

Figure 6. Geogrid installation between the piles.

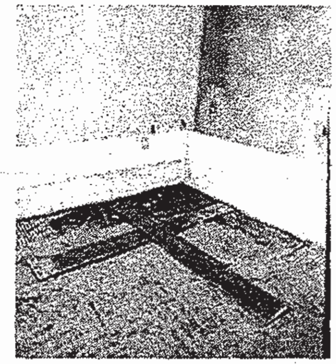

Figure 7. Edge corner of the geosynthetic wall.

vertically directly on the steel plate near the edge of the slope, thirdly wooden planks were installed against the formwork, next the geogrid was laid down with a sufficient length over the formwork for the layer thickness and the tie back length. After laying down and compacting the fill soil, the geogrid was wrapped around the face and fixed in the soil layer with special steel pins.

The vertical part of the formwork was removed to allow a reutilization by the next layer. Due to the very narrow condition behind the concrete facing panel, it was not possible to extract the horizontal part of the formwork, this part was not removed from the construction.

Step by step, the formwork system was raised to achieve the wall.

To prevent a loss of fine sand particles, the wrap around was covered with a geotextile.

By the 90° edge corner, the geogrid was installed overlapped one upon another.

Due to the cramp conditions of installation and the situation between existing concrete piles, it was very important to choose the right machines for soil installation and compaction. Two wheel loaders and 3 BOMAG compaction machines were used. The installation of approximately 200 to 300 m³ of soil per day was possible. By the last three layers, the soil installation in front of the construction was only possible by hand while no machine could drive under the concrete beam of the second level of the warehouse.

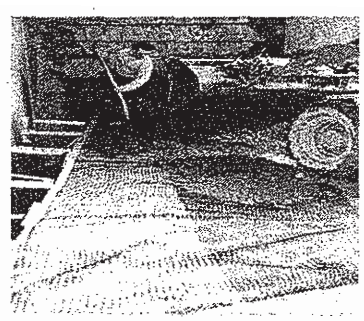

Figure 8. Installation by hand.

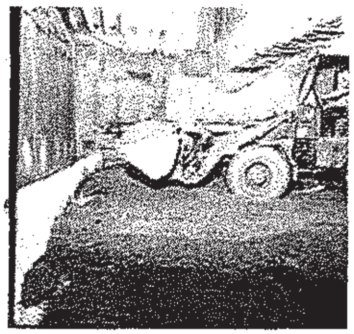

Figure 9. Situation at the upper layers.

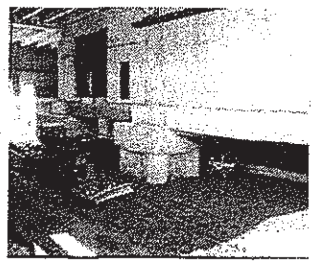

Figure 10. General view of the construction site.

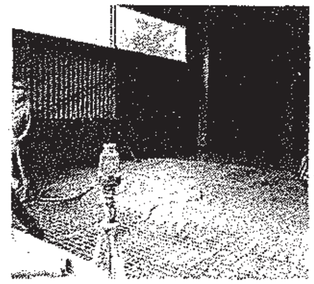

Figure 11. Concrete plate on the second level above the geogrid reinforced wall.

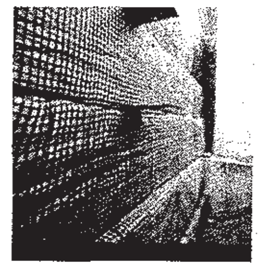

Figure 12. Gap between the concrete facing and the geogrid reinforced wall.

Between the piles, the geogrid was cutted and fixed all around the perimeter of the piles with steel pins. A gravel layer was well set direct by the last geogrid layer to allow a 100% contact of the concrete plate base with the geosynthetic wall.

5 CONCLUSIONS

In a total, 3506 m^3 of soil and 7000 m^2 geogrids were installed.

The geosynthetic wall was achieved in 3 and ½ months between April and July 1999. The weather conditions were optimal to allow the use of the rubbles without problems.

On the other side 742 m^3 concrete and 80 t steel were economized by the construction of a retaining wall and a concrete base plate.

The geosynthetic wall is now always visible, a door allows the easy access to the wall between the concrete facing panel and the geosynthetic face. An air circulation enables the visit and control of the construction.

Outside the warehouse, a second similar construction helps the construction of access ramps to the second level of the warehouse.

In a total, approximately 51.000,00 € were saved by using a geosynthetic reinforced wall.

REFERENCES

Landesgewerbeanstalt Bayern, Grundbauinstitut. Nachweis für die äussere und innere Standsicherheit von Polsterwänden, Benutzer handbuch.