Geotextile structures used for the econstruction of the Motorway Munich–Salzburg

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ABSTRACT: Within the reconstruction of the motorway BAB A8 Munich-Salzburg in the area of the lake "Chiemsee" different special geotextile constructions were used due to very poor underground soil conditions with very low bearing capacity. In the widening area of the road consolidation surcharges were installed as preliminary measure to reduce the later settlement and to equalize the consolidation situation of the underground of the old and the new part of the road. To increase the speed of consolidation geotextile coated gravel columns were used as vertical drains. Reinforcement of the soil was an additional effect of this. For the reconstruction phase of a bridge a bypass drift was necessary which was constructed with geotextile reinforced steep slopes. With a length of 300 m and a height of up to 5 m it was one of the first reinforced slopes directly under heavy motorway traffic in Germany. Two different reinforcements were used (geogrid, composite). Lots of measuring equipment were installed. After finishing the construction of the new bridge the trafic was removed from the reinforced steep slopes were ready for test loadings to look at the load/deformation behaviour of the slopes. Anchors were installed as an abutment and loadings up to 800 kPa on an area of 2.5 m x 2 m were possible. Failure mechanisms could not be observed, deformations were rather small.

1 INTRODUCTION

1.1 *Historical situation*

The motorway BAB A8 from Munich to Salzburg (134 km) was built in the years from 1933 to 1939, including the part along the lake Chiemsee finished within 2.5 years.

The cross section of the motorway consisted of two carriageways (7.5 m each) and a hard shoulder of 1.0 m but no emergency lane. This cross section was kept until the now executed reconstruction.

After a 50-years period of usage with several minor replacements a general rehabilitation was necessary for the road pavement structure and the bridges. An expansion of the cross section with an emergency lane had to be carried out due to the rise of the traffic load from formerly 1000 to now 45000 cars per day, which resulted in lots of accidents and traffic jam. Also the drainage was not sufficient and not according to actual environmental conditions and had to be improved to prevent the Chiemsee from pollutions through the waste water of the road.

Planning of the highway project started in the year 1991 and the execution phase started in summer 1995. Due to nearby nature conservation areas and to the lake Chiemsee the cross section widening took place symmetrically and the new building of the bridges in 2 sections separately for each carriageway. For the maintenance of motorway traffic with 4 driving lanes in each building phase extensive building interim solutions were necessary because of the available only 9 m narrow roadway. The total amount of costs will be approx. 115.0 millions DM. The main construction work was finished up to the year 2000.

1.2 *Underground conditions*

The construction site was situated mainly in the bank and landing area of the Chiemsees. The soil conditions are very heterogeneously in layer sequence and height with great changing also in very narrow areas. Mainly surface layers consisting of gravel, sand or mix-granular soils with a relative density from loose to medium dense were found. In many areas peat and moorland layers near the surface with layer thickness between 0.5 m and 15 m were found in a range from low to high decomposition. As main soil type lake silt was present, which was usually addressed as very soft to soft consistency, sometimes liquid, sometimes stiff.

It reaches large depths (e.g. with the bridge over the river Tiroler Ache to 60 m under ground level) and can be present as fine sandy silt with intermediate plasticity up to organic clay with high plasticity. The compressibility and the settlements resulting from the lake silt are very large and in layers very different. The shear strengths partly are very low and lead to substantial stability problems. Lake silts are usually very sensitive with partly thixotropic characteristics.

The footwall is formed by conglomerates and deposits of the molasse (sand and clay stone) in depths from near the surface in approx. 3 - 4 m under ground level, partly up to depths of 70 – 80 m under ground level.

2 GEOTEXTILE CONSTRUCTIONS

Only in a few areas a full soil excavation to more loadbearing layers was possible. In the predominant part of the site a soil exchange was not possible due to the high water level (often ground level and above) and too deeply being situated loadbearing layers. Additionally deeper excavations would have endangered the stability of the existing motorway dam.

Fills over the pending soil were executed on geotextil separation layers, partly with additional reinforcing geosynthetics. Within the area of the new emergency lane a consolidation dam was applied to take away most of the settlement before the final construction and to adjust the bearing capacity and the consolidation status of the existing and the new roadway section.

In different areas the underground or the geometrical boundary conditions were so unfavorable that additional measures had to be taken.

2.1 *Geotextile coated gravel columns*

For the acceleration of the consolidation of plastic and soft soils vertical drains were used, usually in the form of sand drains, prefabricated paper or geotextile strip drains. With this drain elements water is to be derived from the soil as pressure-free as possible and the consistency and the loadbearing capacity of the soil should be increased.

For the soil conditions pending here these drain systems have to less water flow capacity in longitudinal direction and as main disadvantage a too small resistance against the expected movements/settlements of 0.5 to 1.0 m. At this size of deformations the stability of the shape and hydraulic effectiveness of these drains are no longer given. A further criterion is the installation of the drains, which usually takes place with heavy devices, that could only be used by additional expensive remedial measures due to the very weak subsoil.

Geotextile coated gravel columns represent an advancement of the vertical drains, particularly for extreme conditions. Apart from the support of the consolidation an additional reinforcing of the soil takes place.

Figure 1: Installation of geotextile coated gravel columns

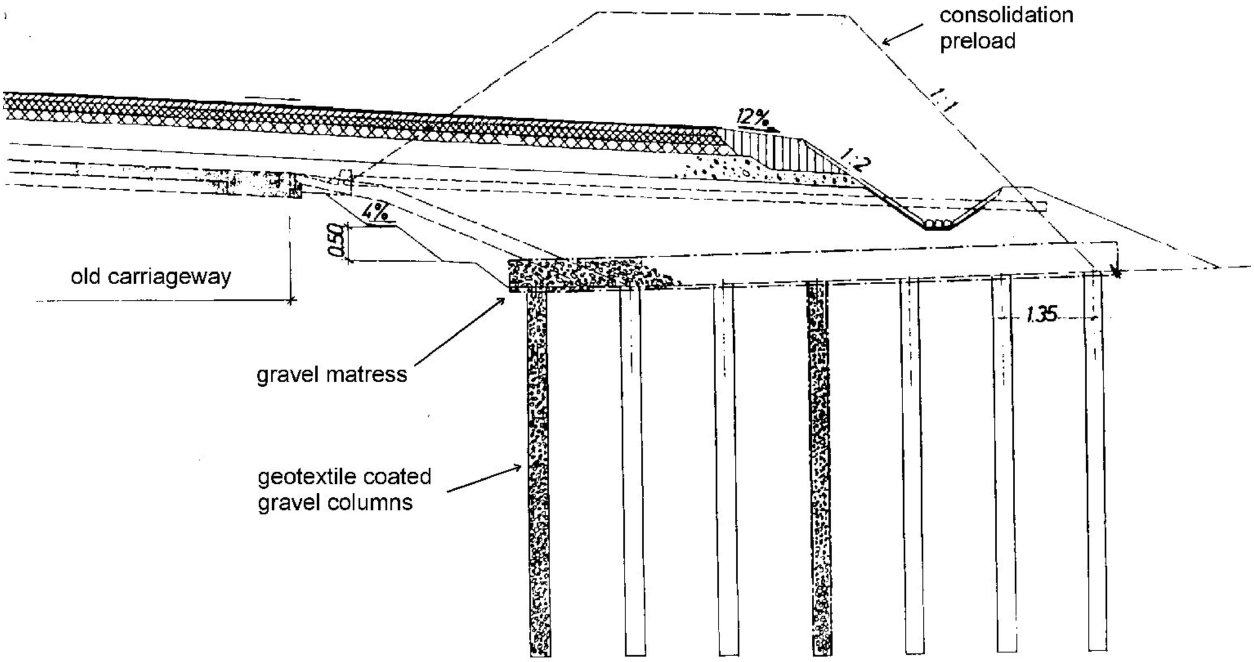

Figure 2: Cross section of consolidation preloading with geotextile coated gravel columns

Geotextile coated gravel columns consist of a hose from a high-strength woven fabric with a diameter of approx. 20 cm sewn at the foot. This is pulled over a steel tube installed at an excavator, filled with gravel or splitt (fig. 1) with a granulation 8/16 mm and then pressed into the soil. A raster of the insertion points of approx. 1.5 m in the triangle was used. The maximum length of the columns is limited by the arm construction of the excavator and is usually within 5 - 6 m. The installation process lasts only few minutes for one column, so that daily perform-ances of approx. 150 gravel columns are usual.

The measure is particularly recommended at very low bearing capacity of the subsoil, where the strength of the excavator is sufficient for the impression process. Gravel or sand layers near the surface can be penetrated with special base shapes or pre-drilling.

After completion of the gravel columns a "gravel mattress" (see paragraph 2.2) is usually inserted as load distributing layer. Above this layer the dam construction with an additional surcharge height of approx. 2 - 3 m was built up. The settlements were measured with plate gages. Dependent on the settlement process the further construction process was controlled. After fading of the main primary settlements the additional fill was removed and a provisional road structure was created.

Apart from the settlement measurements near the surface the distribution of the settlements over the depth were checked in a special trial section with a measuring device based on a metal detector and installed metal rings in different depths. Changes of pore water pressures as well as horizontal deformations in cross sections with and without geotextile coated gravel columns were registered, in order to gain additional experiences for further sec-tions.

2.2 *Load-distributing reinforced soil bodies ("gravel mattress")*

Over the above mentioned gravel columns usually a load distributing soil layer is carried out. At very weak subsoil conditions this was done by a so-called "gravel mattress", where a gravel layer is totally covered by a reinforcing geosynthetic. This measure is used within different areas also without underlying gravel columns as stand alone design feature.

For this at the edges of the section to be covered an auxiliary formwork is set up, the lower part of the geosynthetic layer is inserted and the gravel fill is applied in a height from approx. 40 to 50 cm. After compacting this soil layer the excess lengths of the geosynthetic from the lower position are turned up and connected over the gravel fill for direct force transmission. When using woven fabrics as reinforcing elements this could be achieved by sewing with a appropriate site hand sewing machine. For geogrids bars, rods or cable straps could be used.

A systematic prestressing of the reinforcing geosynthetics, as it was executed in other sites, was not used. Rather it is assumed, that the settlements occurring during the building phase induce strain in the reinforcing geosynthetic sufficent for appropriate force transfer.

2.3 *Dam foundation within a former pond*

In a short section the new southern roadway had to claim land from a former pond. The exploration of the subsoil showed very soft to soft lake silts strata in depths up to 15 to 20 m under ground level in the middle of the site in longitudinal direction. At the edges of the area the height of the lake silt decreased strongly and the underlying molasse came near the surface.

The first thought solution was a sheet pile wall as boundary to the pond, which could not be executed due to the soil conditions for static and production-technical reasons. Also bored piles or a bog bridge were not possible or too expensive.

To check the possibility of a earthwork-technical solution a trial section was executed with an instrumented fill. From an intermediate level a surcharge fill of approx. 2.5 m was created without additional reinforcement on a length of about 50 m within the area with the lowest load-bearing capacity of the subsoil. The deformation measurements and back calculations of stability showed that by additional constructional measures and rein-forcing with geosynthetics a sufficient stability for the final state could be achieved.

The embankment was formed by a rock fill on a nonwoven (mass per unit area m_A = 1000 g/m²) by swimming the nonwoven into the pond, placing the fill on it and dip the nonwoven to the ground. By this way the stability of the system was increased substantially.

In the actual roadway cross section the lowest reinforcement layer was a biaxial geogrid for load distibuting in longitudinal an transverse direction. After an intermediate gravel layer a “gravel matress” with an uniaxial geogrid (main tensile direction transverse to the roadway, tensile strength T_{max} = 110 kN/m) was installed.

The execution of this earthwork-technical solution meant a reduction of about 0.7 Mio. DM related to the original planning. Measuring the final building now for about two years showed nearly no subsequent settlement and good experience under traffic load.

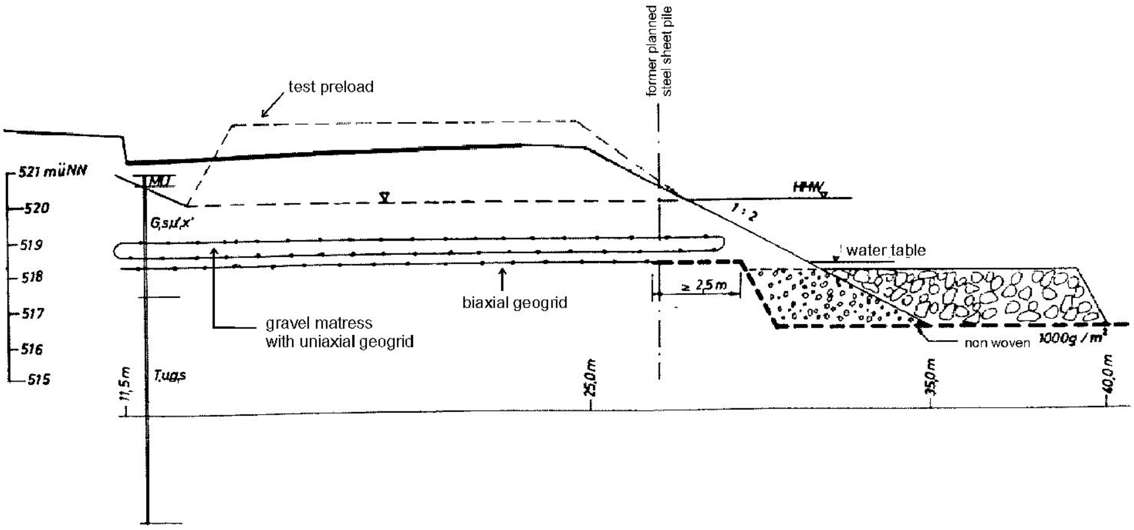

Figure 3: Cross section of embankment construction within former pond

Figure 4: Installation of “gravel matress” within former pond

2.4 *Reinforced steep slope under heavy traffic load for temporary purpose*

Within the area of the river “Tiroler Ache” the old embankment and the existing bridge had settled both since construction on the average of about 0.8 m. Since the flood discharge section was no longer given, the bridge superstructure needed rehabilitation and widening, the rebuilding of the bridge was necessary. For the construction period (about 3 years) a traffic dislocation to the south became necessary to enable the reconstruction of the bridge at the original place. A solution with a minimum space consumption was searched for to protect precious nature reserve forests.

Figure 5: Location for temporary reinforced slopes at river “Tiroler Ache” within nature reserve areas

Due to expected great absolute and differential settlements within this area a flexible, geotextile reinforced steep slope was designated for this temporary building. On a length of approx. 300 m two walls with a height up to 5 m were established. The design and calculations were oriented at the actual german regulations (FGSV 1994, DGGT 1997).

For the front formation "steel grid elements" consisting of a preformed structural steel fabric were used, which served with an inserted wooden plate as lost formwork.

For fill and backfill a nonfreezing, coarse-grained material (sandy gravel, round-edged) with a maximum particle size of d_{max} = 70 mm was used.

As reinforcing materials two different products were used. The wall west (wall 1) of the river “Tiroler Ache” was executed with a geogrid made of high-strength polyester filaments with a polymere protective coating (product A). The maximum tensile force of this product is T_{max} = 155 kN/m.

The second wall (wall 2) was reinforced with a composite material consisting of high-strength polypropylene filaments mounted on a mechanically bounded nonwoven (product B). The maximum tensile force of this product was to T_{max} = 227 kN/m.

For both products in the advance the damage during installation was examined with the installation in an experimental field on the building site with the pending soils and installation equipment. From this procedure for the products reducing coefficients of A_2 = 1.6 (product A) or A_2 = 1.3 (product B) were determined.

By the prefabricated reinforcing elements (front formation and geotextile reinforcing material in appropriate length) a problem-free, effective building operational sequence was possible. During the execution of construction it was found that the front elements were not able to resist the earth pressure from installation and compaction of the fill material without additional support. Therefore steel angles were used as provisional supporting items, which were again removed after completion of the layer after the next.

With the composite material (product B) even with careful handling it was not possible to prevent an substantial amount of reinforcing yarns to became detached and being no longer effective for reinforcing. This "damage during installation" was not covered in the reducing coefficients and the reinforcement had to be balanced therefore by additional reinforcing layers.

Figure 6: Temporary reinforced slope under heavy motorway traffic

As the walls were directly under heavy motorway traffic and no experience existed for this special topic in Germany, an extensive measuring program was installed. This program was also necessary due to the highly compressible and strongly changeable subsoil conditions with resulting large settlements. Both, vertical and horizontal extensometers, bowden cable displacement gauges as well as earth pressure and pore water pressure transducers were inserted in the wall and in the backfill. The results are tied up over extensive geodetic measurement.

Finally approx. 40 cm total settlement of the system were achieved in the roadway area, mainly from a depth of approx. 10 - 30 m under ground level. This was expected because of the geometry of the dams and the weak conditions of the lake silt at this depth. From this total settlement approx. 30 cm occurred during the execution of construction, so only approx. 10 cm settlement had an effect on the finished roadway. For these amounts of settlement the bridge superstructure and the asphaltic surface were adjustable.

The observed horizontal deformations of the walls (1.5 to 2.5 cm for wall 1, 3.5 to 5.5 cm for wall 2) resulted mainly from the installation phase. In particular wall 2 with the product B clear bulges of the front elements leads to an optically non attractive front. Since completion of construction the measured horizontal deformations were appropriate for the wall and with values under 1 cm in an expected, harmless area. Here also the substantial amount of traffic directly over the reinforced soil fill showed no significant effects.

After finishing of the bridge construction measure the steep slopes were not longer needed and ready to be removed. Before this the opportunity was taken to examine the reserves of load-bearing capacity of this reinforced fill system in a full-scale test loading.

Figure 7: Cross section with loading system

As dead loads were expected to be not sufficient to stress the walls, 6 ground anchors with length of 15 m each were installed for each of the two walls. Between this 6 anchors used as abutment a loading system was built with a loaded area of 2 m x 2.5 m. With 4 hydraulic pistons a maximum load of 4000 kN was possible. The maximum pressure reached during the test was 800 kPa for the wall with material A and 600 kPa for the wall with material B. This resulted only from failures of the ground anchors (pull-out resistance and reaching the yield point of the steel).

Figure 8: Ground anchors as abutment for test loading of the reinforced slope

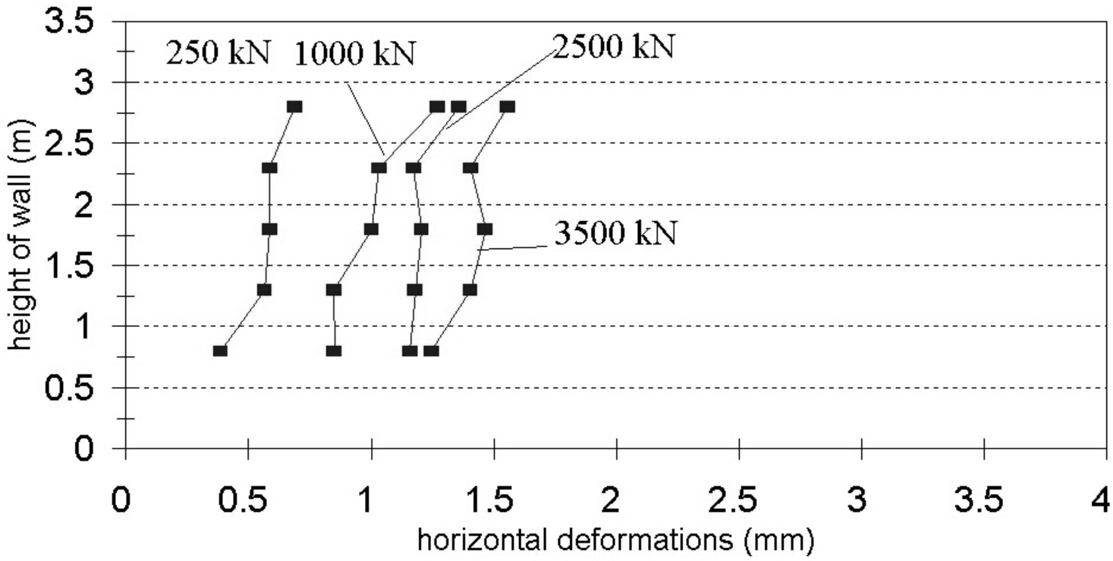

Figure 9: Horizontal deformations of wall 1 during test loading (geogrid reinforcement)

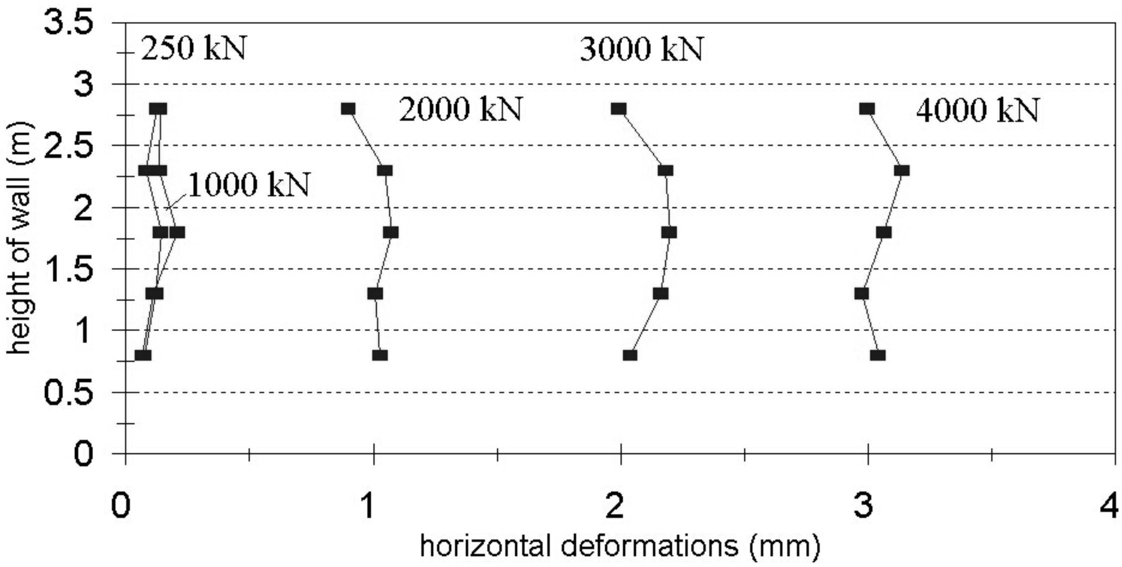

Figure 10: Horizontal deformations of wall 2 during test loading (composite reinforcement)

The observed horizontal and vertical deformations are shown in figure 9 and 10 and demonstrate the good performance of the constructions. There was no sign of failure anyway. As the walls were calculated due to the actual standards with only the necessary factors of safety and a traffic load of p = 33.3 kPa, the surcharge of 20 to 25 times the design value shows the reserves of the systems bearing capacity or the possibilities for optimizing the calculation methods.

3 CONCLUSION

Due to extreme changing and very weak subsoil conditions at the rehabilitation of the motorway BAB A8 Munich – Salzburg different, special geotextile construction measures were taken to solve the soil-mechanical problems, the tasks of the construction management and environmental problems in an economical way. The effectiveness and security of these constructions could be documented by an accompanying instrumentation and monitoring and an extensive full-scale test loading of a steep reinforced slope.

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