Case Study: Carpark on peat - Combined construction techniques using geosynthetics and results of field measurements

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ABSTRACT: During the development of new industrial real estates and medium size consumer markets inhomogeneous subsoil with extremely low bearing capacities are often encountered in Northern Germany, which can roughly be summarized as peat and clay. In this case combined foundation procedures have to be carried out under pressure of time and partially under very narrow intra-urban conditions. Under these conditions combinations of pre-loadings, vertical drainage systems, geogrid reinforced base courses, partially amended by soil improvements, could successfully be carried out. The main focus of the considerations is the evaluation of very large differential settlements of up to one metre, connections to constructions and the constructive solutions required for this.

1 INTRODUCTION

During the development of new industrial estates, the main focus is laid on infrastructural as well as economically structural decision criteria and not on the bearing capacity of the soil, which is not explicitly considered.

In Northern Germany there is regionally more and more a lack of "good" subsoils with a high bearing capacity. Thus, it is often decided to choose real estates with subsoils having an extremely low bearing capacity and which are inhomogeneous. Especially those regions near water are shaped by partly > 15 m thick Holocene peat and clay soils, so that classical measures such as improvements of the subsoil (soil exchange, concrete piles) or deep foundations would be uneconomical.

However, in order to ensure the efficiency of a construction project on soils with a low bearing capacity, alternative, cheap foundation techniques must be carried out which would tolerate a certain number of subsoil settlements and deformations without restraining the serviceability of the planned construction. Thus, the definition of the serviceability has a special importance

The following practical example shows the construction of a 10,000 m² large parking area, also designed to accomodate the heavy traffic (40 t) resulting from the delivery of goods for three special markets. This parking area will be installed on a Holocene peat soil in Northern Germany with pre-load ballast and the installation will imply vertical drains as well as a geogrid reinforced base course.

2 INITIAL SITUATION

The building site overgrown with trees and bushes is located in the former flood and silting area of the Schlei fjord in Schleswig-Holstein. Owing to the permanent land water logging, to a large extent sub-hydro peat soils have been developed with thicknesses of several metres. This decisively influenced the general situation of the subsoil. The thicknesses of the peat are partly > 11 m. Pleistocene sands and/or glacial basin sediments are located below the peat layers (s. Photograph. 1).

Photograph 1. Construction field after deforestation/clearing works

For the peat water contents of between 250% - 600% and coefficients of compressibility of 0.2 MN/m² - 1.00 MN/m² are determined. The shear strength parameters are in layers to some extent considerably varying. They are assumed at average with a c_u-value of 10 kN/m² (apparent cohesion) or 2 kN/m² (effective cohesion) respectively, and a shear angle of 8.0° - 12.0°.

An accessibility and trafficability of the primary area was to some extent impossible.

The ground water level of this building site correlates with the precipitation as well as to the water level of the Schlei fjord. According to the official gauge water level the groundwater variations can be up to 2.50 m and would thus be located far higher than the ground level and the future planning level.

However, a road dam near the shoreline of the Schlei River acts as flood control measure. The continuous supervision and regulation of the ground water levels are carried out by means of a pumping station (coastal pumping station) so that a relative constant level of the groundwater below the primary is kept.

A special problem for the construction of traffic areas are prior service pipes (gas pipes DN 200, water pipes DN 200 and several power supply lines as well as a transmission line) running along the area of the construction site. The gas pipes are located in depths of 0.20 m to 0.60 m below top ground surface.

3 SOLUTION

For the construction of the traffic areas the rates of settlement of the foundation/subsoil were reduced to a tolerable degree by a consolidation acting cover with a thickness of 2.50 m. Moreover the time of consolidation is adjusted to the predetermined time frame of 6 months by using vertical drains.

The stability of the load fill during construction and at final stage as well as the equalization of differential settlements could be guaranteed by installing three geogrid layers.

The design of the "cover material package" is shown in figure 1.

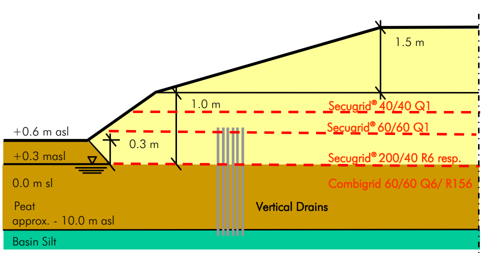


Figure 1. Design sketch

In order to avoid damages resulting from the covering or the immediate and consolidation settlements, respectively, of the gas, water and power supply lines running through the construction site these were installed again in the margin area of the passenger car parking area on a concrete roadway (see photograph 2). The loads have been transferred into the stable soil layers via unreinforced, vibration-free concrete piles.

Photograph 2. Re-installation of the service pipes

In the area of the access road the crossing gas-main service pipes could not be installed so that in this case a complete soil exchange instead of a soil preconsolidation has been carried out. The peat layers have been exchanged by means of a guide rail formwork with an RC-material which has a high bearing capacity and which is compactable. The peat layers had a maximum thickness of 3.00 m. The replacement material has been separated from the in-situ soil by means of a nonwoven and has afterwards been stabilised by means of geogrid layers (see photograph 3)

Photograph 3. Soil exchange by means of a guide rail formwork

4 STABILITY ANALYSIS AND CONSOLIDATION CALCULATIONS

The stability analyses against slope failure were carried out according to DIN 4084. They resulted in sufficient stabilities during construction as well as at final stage. The tensile strengths of the considered reinforcing layers have been reduced according to EBGEO by the proven, product-specific factors.

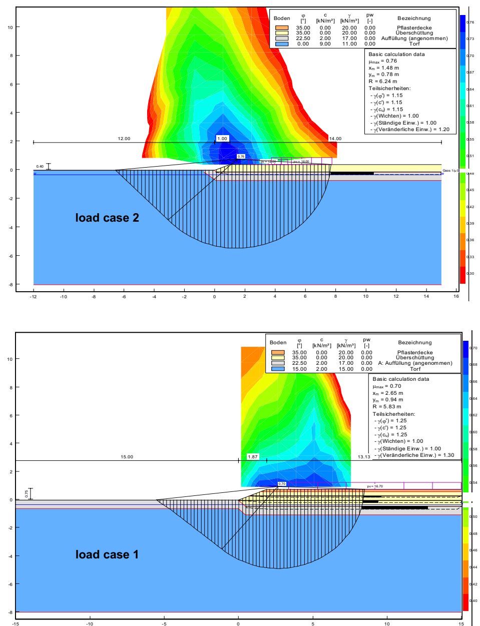


Figure 2. Stability analysis according to DIN 4084 for the construction phase and for the final stage

The estimation of the consolidation settlements and the time settlements has been carried out numerically according to the difference procedure because a system with more than one layer as well as a heterogenic pore water pressure distribution had to be considered.

The information used for this solution are described in detail in Braya M. Das (1983), Advanced Soil Mechanics and have been implemented by the software "Consolidate" supplied by GGU.

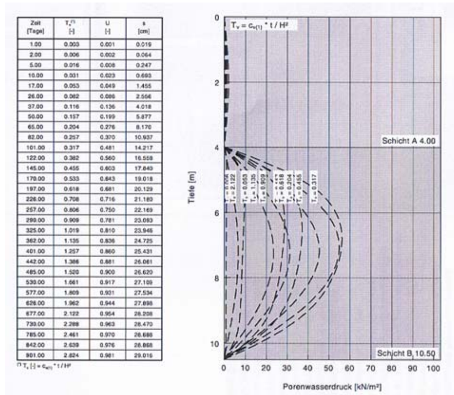


Figure 3. Consolidation Calculation

5 CONSTRUCTION PROGRESS

For the preparation of the construction site, first the available tree population had to be cut down near above the primary area and if possible in the case of low dimensions of the tree trunks of ≤ 10 cm the tree population had to be cleared. Stubs which stick out the plane had been brought into line with the available top ground surface by means of available unpolluted cover material. The deforestation and clearing works were complicated because the boggy area was in some parts not trafficable. For this reason the tree population could only manually be cut down and/or cleared as well as retrieved from the more stable area sections.

Before the first cover layer was installed a combination of separation layer and geogrid, a Combigrid 60/60 Q6 (polyester) R165 of the company NAUE GmbH & Co. KG, had manually been laid out on the primary area in direction to the covering with an overlap of 0.70 m (see photograph 4).

Photograph 4. Installation of Combigrid 60/60 Q6 (polyester) R 156

The reinforcement was protected from displacements by means of cable ties because of the weak subsoil. In the outer edge of the construction site one 20 m wide layer of Secugrid 200/40 R6 has been installed with a crosswise overlap of ≥ 0.50 m and constructive joints with cable ties on a nonwoven (Secutex R504) (see photograph 5). The installation was carried out orthogonally to the area edge, where the overlap in direction to the mid of the construction site was 1.50 m. Moreover, the first two cover layers in the edge area have been wrapped around with the nonwoven because it must have been assumed that the settlements are high and thus also in this area a long-term separation from the in-situ soil could be assured.

Photograph 5. Installation of Secugrid 200/40 R6 above Secutex R 504

A concrete recycling material with a grain size 8/45 was at first used as fill material. The use of this material resulted in a high interlocking effect with the reinforcing geogrid layers and it has moreover been - regarding an area infiltration - characterized by its very high drainage capacity.

The installation and compaction of the bottom fill layers which had a thickness of approx. 0.50 m was carried out only mechanically by driving on the area with a slight peat crawler, the total weight of which is restricted to a maximum of 10 t with a uniformly distributed load (udl) of 12 kN/m².

The delivery of the fill material by means of a trailer truck could already be carried out on the first cover layer (see photograph 6), so that is was not necessary to install an additional reinforced construction road. In order to guarantee the ground failure during the construction phase the temporary installation of soil heaps with dH > 1.0 m on the first cover layers was not allowed. A minimum distance to the filling edge must also not be lower than 5.0 m.

Photograph 6. Installation of the first filling

Starting from the 0.50 m thick cover layer or working plane respectively the installation of the vertical drains (see photograph 7) with a strip width of 50 mm and a medium installation length of 8.00 m (minimum 4.50 m and maximum 13.00 m) is carried out. The drainage distance to each other in the triangle raster was 1.75 m - 2.00 m. However, dry holes could be expected because of the stubs and roots which remained in the subsoil. The uniformly distributed load (udl) of the equipment which is used for the manufacture of the vertical drains (stitcher) must not exceed 16 kN/m². For the equipment additionally a distance to the filling edge of minimum 3.00 m has to be observed depending on the total weight.

A closer approach was only allowed after approval of the experts for the foundation and after evaluation of the trafficability of the area.

Photograph 7. Installation of the vertical drains

After the vertical drains had been installed and after the foundation had been levelled a second reinforcing layer Secugrid 60/60 Q1 (polypropylene) was installed over the total area with an overlap of 0.50 m (see photograph 8).

The thicknesses of the first cover layer (gravel or concrete recycling material with a grain size of 8/45) vary depending on the morphology of the foundation from 0.45 m to approx. 0.75 m and 1.00 m to 1.50 m within the drainage channel.

Photograph 8. Installation of the second geogrid layer, Secugrid 60/60 Q1 (polypropylene)

Another approx. 0.35 m thick fill of a graded concrete recycling material (grain size 2/45 - 8/45) was installed on top of the second geogrid reinforcement. A Secugrid 40/40 Q1 material with an overlap of 0.30 m is installed as third and last geogrid layer. On top of this construction up to the planned final height of the preload fill with a thickness of 2.50 m above the non consolidated area a concrete recycling material with a grain size 0/63 is installed. The installation of the third geogrid layer was primarily scheduled to be optionally installed after having removed the preload fill and after having evaluated the bearing capacities. However, the installation was brought forward for economic reasons and reasons of time. The difficulty was to estimate the minimum settlements in order to guarantee the correct depth of the geogrid below the future pavement.

During the compaction works of the single fill layers the compactor as well as the compaction frequency has in each time been adapted to the subsoil conditions. The compaction technique has partly been determined by means of test fields in coordination with the geotechnical engineer. The possibly required additional works and costs resulting from the change of the compaction technique and equipment must be taken into account by the contractor.

The medium slope inclination in the edge area of the preload fill must at the beginning not be steeper than 1 : 3.5. An increase of the slope inclination to the required designed level has to be carried out in coordination with the geotechnical engineer.

6 SETTLEMENT MEASUREMENT AND OBSERVATION

The settlements of the original area surface or their spatiotemporal development, have been regularly measured and recorded in writing. In the case of a reduction of settlements also the measurement intervals have been reduced.

The settlement measurements are carried out by means of settlement gauges, so-called "basic gauges" which are placed, provided with a bar, on the bottom geogrid. Plastic protection pipes protect the bars from damages. The test levels, all in all 20, were installed in grid form and according to the course of the ground level.

Figure 3 shows the temporary rates of settlements. The short-term increase and the change over to the decreasing rates of settlements already after one to two months become apparent. After a consolidation period of altogether 6 months the settlements were only very low because of the preload fill combined with the vertical drains.

The interim increase in the case of some test levels may be the result of further load increases in areas where settlement > 1.00 m occur.

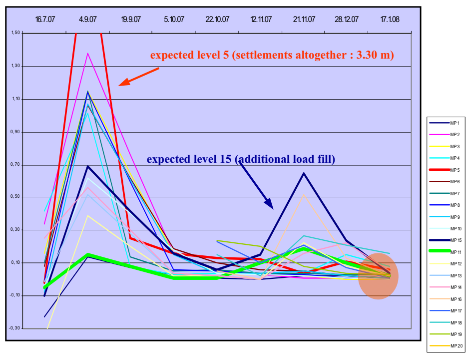
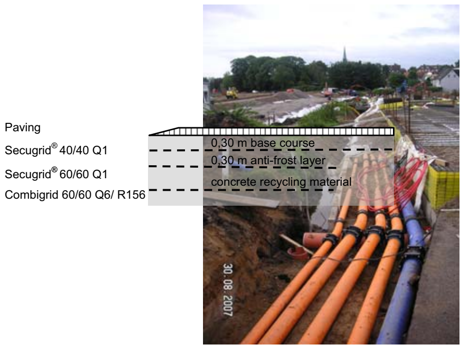


Figure 3. Rate of settlement

The total settlements amount to 0.90 m to 3.30 m and their maximum values were thus above the estimated values. It becomes apparent that an underestimation as well as an overestimation of consolidation settlements in a vertical and horizontal inhomogeneous soil body must always be taken into account. In the described project the differential settlements only led to harmless elongations of the bottom geogrid layer of maximum 2.00%.

7 CONNECTION OF THE PIPE TRENCHES TO THE CONSOLIDATION AREA

The load fill for the soil preconsolidation besides the elevated pipe trenches could only be installed in sections and in layers in order to keep the horizontal comprehensive strengths on the unreinforced CMC concrete piles on an uncritical level. Moreover, the bottom geogrid layers were only installed up to the concrete trench in order to avoid additional tensile strength affecting this concrete trench. Only the top geogrid layer could have been installed across the concrete trench after the decrease of settlements in order to compensate possible differential settlements.



Photograph. 4 Schematic diagram for the pipe trenches

8 CONNECTION OF THE ACCESS ROAD TO THE CONSOLIDATION AREA

In the area of the access road the geogrids were installed in the exchange soil. They were later on connected with the reinforcing layers of the consolidation area by means of overlaps.

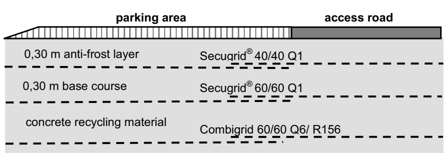


Figure 5. Schematic diagram of the access road

9 FINAL REMARK

Photograph 9. Finished parking area

The construction of traffic areas on inhomogeneous subsoils with a low bearing capacity can economically be carried out by a combination of preload filling, vertical drains and the use of high tensile, stiff geogrids. The residual risk, for example caused by secondary settlements, can often be accepted as to the costs compared to a more expensive, deep foundation which is largely free of settlement.

The implementation involves the exact contractual definition of the serviceability of the client and designer towards the executing contractor.

The possibilities shown for the construction of traffic areas on a peat subsoil which is several metres thick show a perspective for economic solutions by the use of combined construction methods and the use of geosynthetics.

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