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Geogrid-reinforced road embankment over an old dump

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ABSTRACT: A new road designed in the German State of Thuringia crosses an old unconsolidated waste dump area which had been in operation as an uncontrolled landfill before 1950. Analyses of the waste material showed a low content of organic components in the fill body. However, due to some chemical contamination of the fill, there was concern about the expenses which would have arisen for proper handling and deposition of the waste material and for the decontamination of the site, if a partial replacement of the waste with inert soil would have been executed. The favoured solution was, to keep the waste in place and design the road embankment accordingly. For this purpose, the compressibility of the fill was determined by two large scale trial loading tests with geogrid-reinforced test embankments. The test results supported the design of the embankment which is under construction at the present time. The geogrid reinforcement was essential in reducing the total settlements and in particular in smoothening the differential settlements.

1 GENERAL

In Germany difficult soil conditions are frequently encountered in the construction of new roads. Near urban areas space is limited, and often it is not possible to select alternative road alignments to avoid foundation problems, which arise when unfavourable ground conditions are encountered locally. In such situations more elaborate engineering solutions are called for, which may benefit from the application of geosynthetics.

2 LOCATION OF THE SITE

At Saalfeld, a small town in the State of Thuringia, Germany, a two lane road had to be constructed. Parallel to an existing railway embankment which is a little higher than the new road embankment, the alignment crosses the flat valley of the river Saale. In the past, the valley floor had been partially excavated for the recovery of clay, used in ancient construction. The excavated pits had then been refilled with all kinds of materials. The road alignment connects two bridges and must fit with the junctions on both sides of the valley. So it was not possible to realign it and optimize the location of the new road embankment with regard to the ground conditions. The new road had to traverse the fills. So a technical solution had to be found to cope with the unfavorable foundation situation over a length of 170 meters.

When the excavations for construction clay were undertaken back in 1850 to 1880, the explored open pits had been protected against floods by a dam along the river bank which partly still exists, but which is now hidden by backfill. Furthermore, historical records tell that a small creek existed in the area, but nobody knows exactly where it was. So the ground below the foundation of the embankment is very heterogeneous and its mechanical properties can hardly be predicted with the desirable degree of confidence.

3 SITE INVESTIGATIONS

3.1 *Waste analysis*

The waste analysis comprised historical research, sampling and chemical testing. It lead to the conclusion that the waste-backfill is very heterogeneous. The oldest parts of the fill consist of domestic waste from the nineteenth century. Later all kinds of debris and residues were dumped, especially ashes and rubble from buildings which were destroyed during the second world war (1939 to 1945). The waste dumping operations ceased in 1950. Then the entire area was covered with a layer of sand and gravel of variable thickness up to 3 meters. It was subsequently used as a training range for trucks. Due to these activities the waste fill and the predominantly cohesionless cover soils were compacted rather erratically.

3.2 *Geological conditions*

The schematic soil profile below the road embankment can be described as follows:

- From the ground surface to 1,0 to 1,5 meters nonuniforly compacted cohesionless sand and gravel fill
- Heterogeneous, predominantly inorganic waste material until 4 to 6 meters below ground surface
- Soft, grey alluvial clay, thickness 0.5 to 1.5 meters
- Gravel layer of 3 meters
- Sandstone bedrock below the gravel layer

The water content of the deposited waste material varies with its composition and the access conditions of precipitation and surface runoff. Some leachate was encountered at the base of the fill above the impervious clay layer. A continuous ground water table was located in the lower gravel layer. There is a second ground water table at greater depth inside the sandstone.

The waste deposit appears to be well sealed at the base by the underlying clay layer. The investigations for the new road focussed on the local situation and did not include an assessment of the environmental hazard of the entire dump area which extends far beyond. As for the construction of the road, it was decided by the authorities in charge, that the waste should remain in place, because the natural clay at the base acts as an efficient seal.

3.3 *Solutions for the road foundation*

According to the design, the surface of the new road will be 3.5 m above the current ground level. The existing fill is considered an incompetent ground for the foundation of the embankment. Without special treatment the anticipated settlements would be on the order of 20 cm to 40 cm with probably quite substantial settlement differences over short distances. Several alternatives of foundation concepts were evaluated under the aspects of tolerable settlements and differential settlements, environmental issues and costs.

One option with respect to small, well controllable vertical displacements seemed to be a geogrid reinforced embankment on piles. However, besides high expenses, the disadvantage of the deep foundation would be, that the piles would perforate the natural clay barrier below the waste body in order to reach the bearing stratum below. This was considered unacceptable, because it might lead to a contamination of the ground water.

As indicated already, the option to excavate the waste, move and deposit it at an engineered landfill site and replace it with inert soil material, would have caused high costs, additional environmental and technical problems and thus was considered inappropriate. The most promising concept was to place the embankment with additional surcharge well before installation of the road surface in order to preload the ground and thereby reach a high degree of consolidation of the waste material and the underlying soft clay. A reduction of total settlements and elimination of intolerable settlement differences was to be achieved by an adequate soil reinforcement. Since the mechanical behaviour of the waste material could not be predicted on the basis of past experience nor could it be determined by laboratory experiments, it was decided to execute large scale loading tests at the site.

4 TEST ARRANGEMENT

4.1 *Trial embankments*

To study the behaviour of the ground under the designed road embankment of 3.5 meters height and to evaluate the effect of an additional surcharge, two test embankments were erected. Embankment No. 1 was approximately square in plan, 6 meters high, 5 by 5 meters at the crown and about 25 by 25 meters at the base. Embankment No. 2 was 3 meters high, 4 by 4 meters at the crown and 18 by 18 meters at the base. The average unit weight of the compacted well graded sand fill was 1.72 t/m^3. The distance between the test embankments was sufficient to avoid interaction. According to the ground exploration it was anticipated that test embankment No. 1 was placed where the thickness of the compressible layers was largest.

At the base, test embankment No. 1 was reinforced by a single sheet of high tenacity polyester geogrid with a laboratory-tested short term uniaxial tensile strength of 150 kN/m in both directions. The reinforcement of test embankment No. 2 consisted of the same type of geogrid, but with a tensile strength of 150 kN/m in the main direction and 30 kN/m in the perpendicular direction. At the base of test embankment No. 2 two layers of geogrid were installed perpendicularly to each other.

4.2 *Instrumentation*

The area for the trial embankments was carefully selected and surveyed. A system of survey points for the measurement of elevations was installed around the trial embankments and on the adjacent railway embankment (Fig. 1). Horizontal inclinometers were selected to serve as the main measurement instruments for the determination of deformations.

They were placed at the base of the embankments below the geogrid layers (Fig. 2). The inclinometer pipes were installed parallel to the main axis of the road and perpendicular to it. One additional inclinometer measures the settlements along an axis parallel to the road axis under the slope of the embankment No. 1.

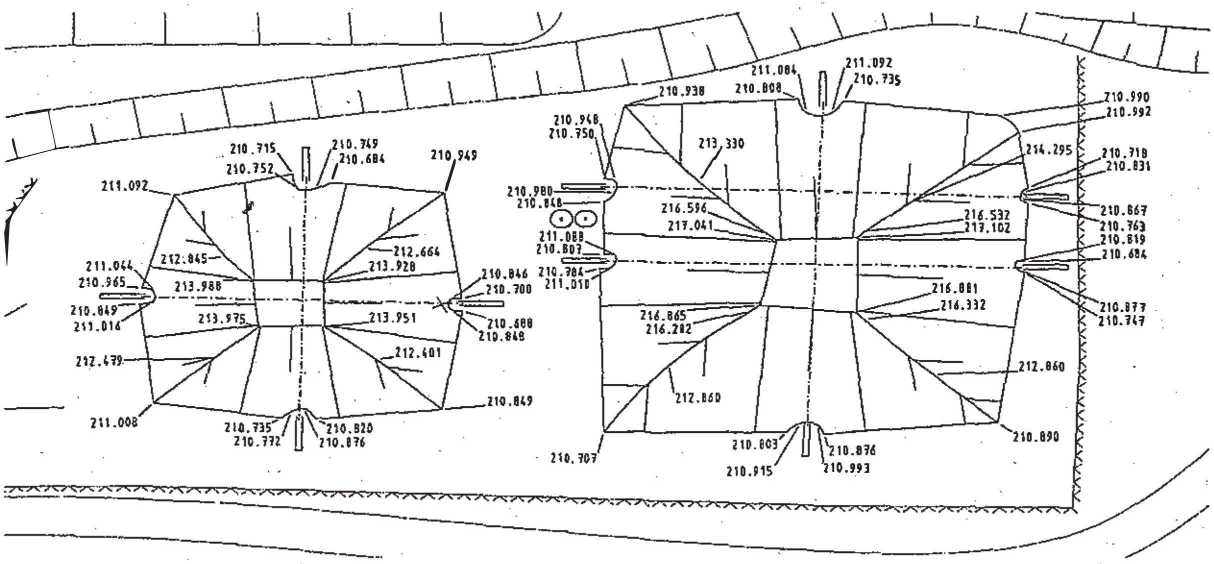

Figure 1. Layout test embankment.

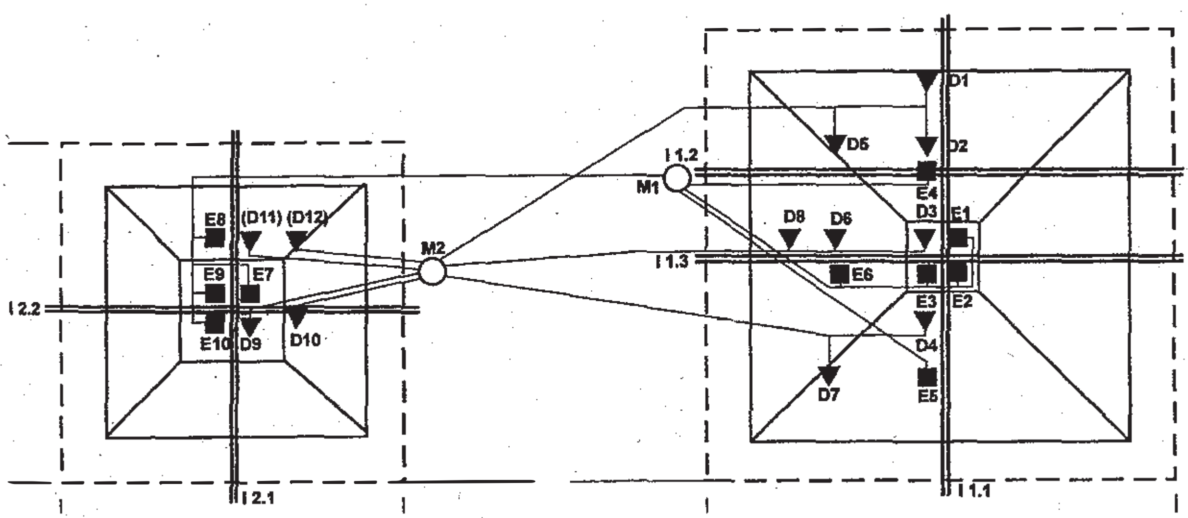

Figure 2. Instrumentation tools: I - Horizontal inclinometers, E - Earth pressure cells, D - Strain gauges.

Earth-pressure cells were installed for the measurement of the vertical contact pressures between the embankment and the ground. The geogrid sheets were equipped with strain gauges to determine the strains and deduce reinforcement forces from these data. Measurement of the ambient temperature and temperature below the embankment completes the monitoring system. The layout of the instruments is presented in Fig. 2.

4.3 *Boundary conditions and effects on settlement*

The heterogeneity of the waste body is probably the governing factor with regard to the expected differential settlements. However, the following boundary conditions may also have a significant influence on the development of the deformations under load:

- the varying depth of the former clay pit which determines the thickness of the fill
- the varying thickness of the soft clay below
- positioning of the road embankment at the periphery of the landfill near the buried slope of the ancient clay pit
- ancient facilities such as a trench with a sever pipe placed decades ago in the waste body with inadequate backfill.

5 RESULTS

Readings were taken at all instruments for 600 days at varying time intervals. During the erection of the embankments monitoring was done currently, then at daily, weekly and finally monthly intervals.

5.1 *Settlements*

The plot of inclinometer data obtained below embankment No. 1 in the direction perpendicular to the road axis shows a very smooth development of the settlement profile (Fig. 3). There are no indications of erratic settlement differences due to irregularities in the compression of the waste layer under load. Evidently, the geogrid reinforcement in combination with the compacted well graded sand fill serves its purpose successfully. All monitored settlement profiles support this observation, although some differences were noticed in the shape of the settlement trough.

The maximum settlement below the higher embankment No.1 amounts to 27.5 cm. Below embankment No. 2 the maximum settlement is only 8 cm. The difference between both test embankments results form the different heights and the different loads associated with them. It is also influenced by the difference in the thickness of the waste deposit below the trial embankments (5 m thick under embankment No. 1, only 3.5 m thick under embankment No. 2). Furthermore, there may have been different local moisture contents inside the waste. Below embankment No. 1 the former creek is suspected which may partially still be an active flume, this may have played a role in the compression of the fill.

During construction of the embankment about 30% to 40% of the total settlement took place. 10 weeks after completion approximately 80% of the total settlement had occurred. The development of settlements with time is plotted on Fig.4. It can be seen, that the settlement due to the placement of the road embankment presently under way, follows the pattern of the test embankment and that the magnitude of the observed deformations falls in between the lines for both test embankments.

It was interesting to notice that the rate of settlement of the smaller trial embankment was initially higher than the rate of settlement of the larger embankment.

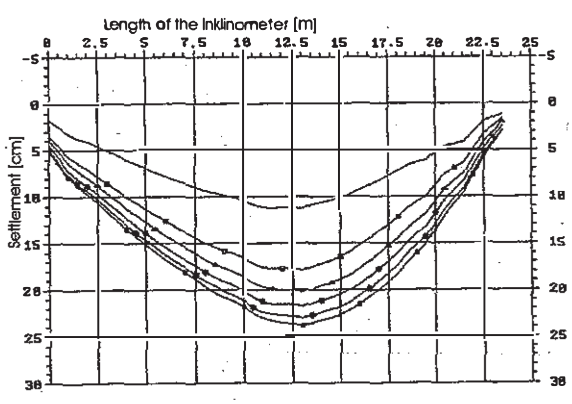

Figure 3. Settlement below test embankment axis I 1.1

The settlements of the test embankments are nearly equal in both measured main axis directions with some minor deviations only due to the reasons mentioned in chapter 4.3. The additional inclinometer under the trial embankment No. 1 determined a differential settlement perpendicular to the road axis within a range of 6 cm at 6 m distance (1%), which would have to be considered significant for the asphalt pavement, if it would occur after completion of the road. But knowing the rate of settlements and the time when time-dependent settlements cease, this can be taken into account in the construction sequence. The calculated elongation of the geogrid amounts to 0.05 mm, which is a small acceptable value with respect to the performance of the reinforcement.

The influence of the embankments on the adjacent area remained only marginal. At the toe of the large embankment No. 1 maximum settlements of 17 mm to 54 mm were measured, while at a distance of 5 m from the toe of the embankments no settlements nor any heave could be detected. The placement of the trial embankment had no influence on the nearby railway embankment. This observation was important for the preparation of the construction procedures. No significant creep deformations were observed.

5.2 *Vertical soil stresses at the base of the test embankments*

The earth-pressure cells placed horizontally at the base of the embankments indicated the following maximum contact stresses at the level of the former ground surface: embankment No. 1 σ = 57 kN/m²; embankment No.2 σ = 47 kN/m². It is interesting to note, that the maximum values measured do not correspond with the calculated peak values below the centre points of the embankments (expected were 105 kN/m² and 52 kN/m² respectively) Since the stresses are distributed quite uniformly in the area of measurement, it is proposed in the interpretation of the measured data, that there is an arching effect within the embankments, specially pronounced in the larger one and that the geogrid reinforcement facilitates this arching with the associated stress distribution at the base of the embankment.

5.3 *Strain of geogrids*

The measured strains are small. For example, below embankment No. 2 for the uniaxial geogrid (150/30 kN/m tensile strength) the measured strains are varying locally between 0.2‰ to 2‰. The average strain of the 12.5 m long geogrid deduced from the measured settlements was approximately 0.2‰. At the perimeter of the geogrid sheet values of 0.4‰ were measured.

The ultimate strain of the geogrid at tensile failure in a laboratory test was 13%.

5.4 *Temperature*

The variations of the temperature registered during the test period remained moderate and had no influence on the measured data.

6 CONCLUSION AND CLOSING REMARK

By large scale testing with two trial embankments on an old waste deposit it was possible to provide reliable information about the compressibility of a heterogeneous fill. The test results were used as the basis for the design of the geogrid-reinforced road embankment. It was thus possible to avoid removal of the waste. The geogrid reinforcement played a key role in the structural performance of the embankment by eliminating intolerable settlement differences and reducing total settlements. It also facilitated a favourable rather uniform stress distribution at the base of the embankment. Currently the road has been under construction. The monitoring program using 6 horizontal inclinometers reveals that at the structure behaves as predicted. (Fig. 4).

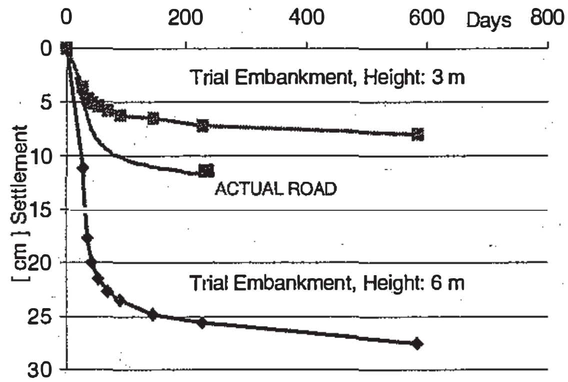

Figure 4. Settlement versus time.