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Cover of a landfill for drilling mud

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ABSTRACT: A basin shaped mud landfill with a size of approx 80 x 100 m had to be covered. The approx. 4 m thick mud was not drained and, therefore, had a pulpy consistency in wide areas.The covering system which was carried out basically consisted of a carrier and drainage layer made of geogrids and bruhswood fascines, sand for the profilation of a roof profile, and a sealing consisting of a bentonite liner. A robust composite material (woven plus nonwoven) was installed on top of the fascine layer to form the separation layer. Thus the usage of five different geotextile layers in total, arranged in three planes, allowed the economic and safe construction of an efficient covering system on top of an extremely difficult subsoil.This paper shall present and explain the marginal conditions which were relevant for the dimensioning and selection of the different geotextile materials. A comparison with other possibilities not using geotextiles will show the advantages of the chosen and executed solution. Slides will illustrate the construction procedure and the solution of construction details.

1. PRESENTATION OF THE PROJECT

1.1 General information

Drilling mud which results from research and extraction drilling is normally stored by the mineral oil and gas producers in landfills for mud for temporary storage or final disposal.The basinshaped landfill for mud which is further treated in this contribution had been formed through pushing marginal dams with a height of approx 3.5 m on their outer face and it has a size of approx. 80 x 100 m. The base and the marginal landfill slopes are continuously sealed towards the subsoil using a geomembrane. The average thickness of the mud amounted to approx. 4.0 m.

Due to the the continuous base seal the water which was stored with the mud and the rain water could not seep away. Thus it was unevitable that the mud surface was covered with water which had to be pumped from the surface from time to time. Since large areas of the mud surface were covered with water, wide areas of the stored drilling mud had a pulpy consistency.

After the storing had been finished it was examined whether the drilling mud could be brought into a municipal waste landfill. This possibility of disposal had to be rejected since the mud - due to its high water content - did not possess the strength which was necessary for the storing on a landfill. Therefore, it was decided to leave the drilling mud on site and to cover the basin permanently by a suitable structure and to thus recultivate the area which is concerned.

1.2 Description of the drilling mud

Comprehensive soil mechanical examinations were not carried out in the preliminary stage of the construction measure since it was not possible to walk on the surface in order to take representative samples staggered through the depth without costly measures. The determination of the grain-size distribution on several samples which were taken from the margin shows that the drilling mud - after the grain-size distribution - is a clayey, fine sandy silt (according to DIN 4022). The water contents laid between $w = 30$ % and $w = 67$ %, however, the samples have been taken accidentally. The fine grain share ($d < 0{,}06$ mm) laid between 60 to 85 %.

Most time of the year the mud being near the surface showed a pulpy consistency. The shear strength c_u which was found out at two of the above mentioned samples under a load of 8 kN/m² (corresponds - since under buoyancy - to approx. 1 m under top edge of the ground) laid at $c_u \approx 8$ kN/m² or $c_u \approx 13$ kN/m².

1.3 Task definition

The covering which was to be planned for the mud landfill had the main task to prevent precipitation water from penetrating. The structure should be of such a kind that a vegetation could settle indepently which could be kept on the location without too much care, if possible. A later economical exploitation of the area was not planned so that this aspect had not be taken into consideration. Due to the protection of the countryside and the nature, the external shape of the site to be built was to be adapted as far as possible to the natural local situation. Of course, in the client's interest the sealing system was to be built as economically as possible considering all requirements.

The peculiarity of the soil put some further requirements at the system to be planned:
The loading which a cover system represents would cause settlements which have to be absorbed by the applied system without any damages.

- A loading on the water saturated mud causes pore water pressures which affect the stability. Therefore, it had to be seen that the cover system had a sufficient stability in the final state as well as especially in all building phases. The considerations had to include the actual mud body as well as the marginal dams limiting the basin which had outer slope inclinations of approx 1:1.
- A consolidation of the burdened mud was only possible by a pore water outflow since the basin is laid out completely with geomembrane. In order to enable the water outflow, an accordingly permeable layer in which the water flowing out by the load could escape had to be installed on the mud surface.
- By chosing an appropriate structure the working and health protection of the people carrying out the construction had to be ensured at any time.

2. DEVELOPING OF THE COVER SYSTEM

2.1 Solution variants in question

In the planning stage different solution variants were discussed in which always the stability of the drilling mud being difficult to calculate, but anyway low was the main problem.

Therefore, one variant consisted in adding binders for stabilization; however, the question how the installation on the surface and the incorporation in the drilling mud could be carried out economically could not be answered satisfyingly.

Another concept consisted of draining the mud through puncturing the vertical drainage in order to increase the strength. This was also rejected already at the beginning since only by costly relief measures a working surface which was sufficiently able to take a load could have been built.

The third variant was the construction of a multi-layered carrier layer made of geogrids and gravel. The lowest layer should consist of a geogrid on which gravel with a thickness of 40 cm should be installed. On this a second reinforcement layer of geogrids should be installed which was to be covered by a 40 cm thick carrier layer made of gravel. The top again consisted of a layer of geogrids. For this structure stability calculations (ground structure according to DIN 4084) were carried out also for possible states of construction These calculations showed that the arithmetical stability can be proved when applying this carrier layer reinforced with geotextiles. Economical considerations lead to a rejection of this variant which would require several layers of geogrid and a 80 cm thick package of gravel.

2.2 Solution which was carried out

When carrying out the final plan it was tried to first create a light substructure being able to take load which could be easily installed on the mud surface. The first measure consisted of installing a layer which enabled a safe walking on the area.

For this purpose a geotextile combination layer consisting of a nonwoven fabric and a geogrid connected together was installed directly on the mud surface. Corresponding calculations lead to the result that a tensile strength of approx. 5 kN/m was necessary in order to make a further covering safely possible. A product with a maximum tensile strength of 15 kN/m (machine and cross machine direction) was required in the tender in order to prevent that this loading would not strain the geogrid layer. Knot stiff geogrids were chosen because of the better load distributing effects.

As nonwoven fabric a product of the robustness class *GRK 3* according to the *FGSV* instructions was required (plungure puncture resistance $\geq$ 1.5 kN, mass $\geq$ 150 g/m²) in order to guarantee a bridging of the screen opening of the geogrids also under stress. In order to keep back the mud on the one hand and not to obstruct the drainage on the other hand, an effective opening size of $O_{90,w} \leq 0{,}1$ mm was necessary. Nonwoven and geogrid were connected as combination layer so that the installation was possible in one operation. Brushwood fascines were laid on the combination layer as light layer with a lot of hollow space in order to absorb the pressure water and at the same time distribute the load. The bundles had a diameter of approx. 20 cm and were laid out by hand crosswise in two layers. The fascine layer had been recommended by the owner of the mud pit who had made good experiences with these load distributing elements when covering smaller pits.

The installation of vertical drains was given up since with that only the temporal consolidation course could have been shortened. The amount of settlement which finally occurs cannot be affected with such measures.

On the double fascine layer it was now possible to put in sand with earthwork devices. A geotextile separation layer was installed between fascines and sand in order to prevent the sand from penetrating into the hollow spaces of the fascines and thus obstruct the drainage. Since with the fascines only a relatively uneven surface can be produced which is highly deformed under stress, a geotextile composite (nonwoven and woven) was required as separation layer which was robust against mechanical stresses. Nonwoven and woven had to fulfil at least the requirements of the robustness class *GRK* 4 according to the *FGSV*-instructions (nonwoven: plungure puncture resistance ≥ 2.5 kN, mass ≥ 250 g/m², woven: maximum tensile strength ≥ 45 kN/m, mass ≥ 220 g/m²).

With the sand a geometry was shaped on which a bentonite liner could be installed as sealing layer. Sand of the group *SE* according to DIN 18 196 had to be supplied since such a soil is already compacted only upon driving at installation so that from this layer later no remarkable settlements can be expected. The profilation of the formation for the sealing took into consideration - with a corresponding superelevation - the settlement differences which could be expected due to the consolidation of the mud.

When chosing the sealing the decision was made in favour of a bentonite liner since such an element can be installed easily and nearly independently from the weather and it keeps its function even with strains. Compared with a geomembrane there was a basic economical advantage which resulted from the construction circumstances and the lower monitoring time that was required.

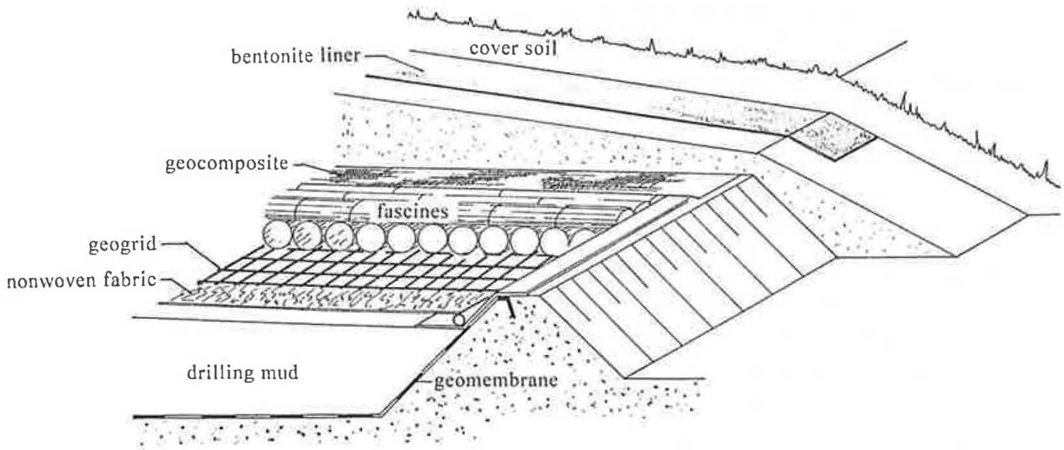
A mineral clay sealing did not come into question since upon correct installation a compaction with a herewith connected dynamical stress (vibration) of the subsoil would have been necessary. Such stresses, however, had to be avoided with regard to the stability. Apart from this fact a mineral clay sealing would be endangered by the possible settlements the amount of which would be increased by the dead weight.

In order to restrict possible strains of the sealing element (bentonite liner) in the area of settlement differences, the lower layer of the bentonite liner was required in the tender as composite nonwoven. Both components (nonwoven and woven) had to fulfill the requirements of the robustness class *GRK* 4. As bentonite weight it was required $\geq 4{,}000$ g/m².

As covering of the sealing and as base for the recultivation a 1 m thick soil layer had to be installed. The chosen layer thickness ensured on the one hand a permanent protection of the bentonite liner against freeze and higher humidity fluctuations and on the other hand, thus, conditions were created which made the vegetation of local plants possible. The entire structure is shown in picture 1.

3. CONSTRUCTION

Originally the mud surface was to be shaped by the owner of the mud basin (with a stripping shovel) in such a way that everywhere there was a gradient to the margins. The consistency of the mud did not allow such a profilation so that the covering had to be installed on the existing surface without any further measures.



picture 1: cover system of the landfill for drilling mud

Despite the state of the stored drilling mud which was in parts liquid, the combination layer could be unrolled by hand and formed directly a surface on which it was possible to walk and which in larger parts is like a water-bed. The nonwoven fabric fulfilled the planned filter function and, moreover, bridged the screen opening (approx. 39 x 39 mm) correctly. The chosing of a knot stiff geogrid was right since a bridging of even the softest areas was possible by the good small-spaced load distribution without a detachment of the nonwoven from the geogrid due to incompatibly high deformations. This would have caused damages of the nonwoven. The junctions of the geogrids were frictionally connected by PE-stripes so that it was possible to walk on the entire surface without any restrictions within the shortest time.

For the observation of the pore water pressure at the following covering of the mud, three pressure boxes were installed within the mud body. From these measurement values which were continuously checked the development of the pore water pressure could be observed in order to intervene in a regulating way in the construction course, if necessary.

On the covered mud surface the fascines could be installed without any problems. They formed a layer, extremely able to take a load, on which the sand could be put in in a thickness of approx. 1 m with normal construction devices (caterpillar) in a head-first-process. The delivering bulldozers were not allowed to drive on the surface. When putting in the sand the movement of the not yet covered surface had to be observed continuously in order to react against heaves due to the covering of sand and to counteract to a failure of the subsoil. By the circular installation of the sand from inside to outside it was on the one hand ensured that a possible ground break could only occur in the middle of the landfill so that the marginal dams were not endangered, and on the other hand a certain profilation of the mud surface could be reached by the squashing of the material towards the middle of the area. Pressure water which escaped at the surface was thus lead to the margin of the basin where a circulating drainage was installed in the fascines. The drainage flows into a control stack being placed in one corner of the mud basin.

On the shaped sand layer the bentonite liner was installed with circulating overlaps of 50 cm. The inclination of the formation was made - under consideration of a security of approx. 100 % - in such a way that after fading of the projected settlements differences ($\Delta s \approx 50$ cm) there is still a gradient of ≥ 5 %. The saturation of the sealing by the control stack was made by simple constructive measures (sleeves). On the sealing, cover soil was installed - for the protection of the stone free bentonite liner - in a thickness of 0.7 m which was covered by 0.3 m soil.

Already after a short period a first vegetation occured without any aid (the nature protection authority had required a natural settlement). This vegetation protected the surface through the winter 95/96 reliably against erosions.

The licensing authority required that the settlement of the covering should be controlled occasionally by settlements gauges which are installed on the surface. The control stack enables a pumping out of the pressure water which will be expected for the following two years. For the long term the efficiency of the sealing can be controlled through this stack.

By means of altogether five different geotextile layers, arranged in three planes, the construction of an efficient sealing system was made possible in an economical and safe way. The entire construction procedure could thus be carried out within only three months, not least because of the experience of the contractor.