A case history of geosynthetics used for the Biffa Landfill site, south of Brussels, Belgium

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ABSTRACT: The authors describe the construction of a waste disposal facility for non-toxic waste with a high content of organic material, South of Brussels. The disposal was excavated 35 m deep in sandy soil. They describe the use of many different geosynthetics and illustrate the long-term performance of similar installations over many years under similar site conditions. The authors show how the study of past geosynthetic installations may be used to guide improvements in the design of modern systems and illustrate how these are incorporated into the latest, large-scale installation in Belgium. Previous cells of the waste disposal facility, built following the same principles of design, have been monitored over 10 years by the analysis of water from the underlying drainage system and by piezometers. These tests show that there has been no loss of leachate, thus proving the quality of the system. Appropriate design, together with a high quality of work execution, make it acceptable to build new waste disposal sites in areas which are, from the geological point of view, not favourable for waste containment.

1 DESIGN OF THE SITE

One of the most difficult aspects of the construction of the BIFFA site was the presence of the deep Brussels Sand layer in which it had to be excavated. It was vital that no pollution from the waste should migrate through the sand to contaminate the ground water table. In addition to original innovative design, safety factors used for dimensioning were based upon the recommendations of Koerner (1998) and Montjoie. During execution, not only was full QA control implemented, but also performance tests were undertaken on the geosynthetics used. Geosynthetics played an essential role in the design and construction of this waste disposal site.

2 BASAL LAYERS

The construction cross section of the basal layers can be seen in Fig. 1 and 2. The bottom of the waste disposal is 1 m above the ground water table. A layer of gravel 20-32 mm diameter, was placed on a geotextile (a) which prevents the loss of gravel into the subsoil. On top of the gravel a separation geotextile (b) was installed and a 600 mm thick layer of clay.

This gravel layer, surrounded by two geotextiles (a and b), provides a firm base facilitating the compaction of the clay whilst also acting as a capillary barrier against the migration of water and subsoil particles. Geotextile (b) with an O_{90} smaller than 50 microns, placed beneath the clay layer, prevents the downward migration of particles from the clay and the clogging up of the drainage layer.

Above the clay was installed a 2 mm HDPE geomembrane (c), with two smooth surfaces. Hot wedge double welding was used and each seam was checked for integrity by means of either an air pressure test, an electric wire test or a vacuum chamber test, depending upon its situation. The geomembrane is protected by a layer of sieved sand 150 mm thick and two geotextiles: a nonwoven geotextile of 300 g.s.m. weight (d), together with a 60 kN/m strong woven (e). Before approving the geotextiles used, a cylinder test was executed, simulating an overburden load of 50 m of waste on the geotextiles, the sand and the geomembrane (following Test Standard prEN 00189055 'Protection Efficiency'). The combination of a woven and a nonwoven geotextile together with 150 mm of sieved sand, proved to be an effective protection layer for the geomembrane.

Fig. 1 and 2. General view of the basal layers with Terralys geotextiles being installed.

For future projects, this combination of sand and geotextiles could be replaced by one single heavy duty geotextile. One of the advantages of replacing the 150 mm of sand by a relatively thin but strong geotextile would be that, apart from the gain in volume for waste, the hydraulic gradient on the geomembrane and the drainage system is reduced by 150 mm.

A layer of stones 56-120 mm diameter was installed and a woven geotextile (f), with an O_{90} of approx. 300 microns, was placed on top in order to avoid infiltration of particles into the stones when the facility is filled up with waste. For future projects the O_{90} might well be chosen larger to improve permeability and to avoid potential clogging and blocking. The stones must be able to support the high load of 50 m of waste without being crushed. They should not be chalk or contain chalk, because degradation would be caused through contact with low pH leachate during the later stages of the site's life. Contaminated water, seeping through the waste, is evacuated by gravity through this 300 mm thick drain and collected at a central point. From there, the leachate is pumped to a special treatment plant located on site. Before treated leachate is released to the river Hain, its quality must be within the Wallonia regional environmental standards.

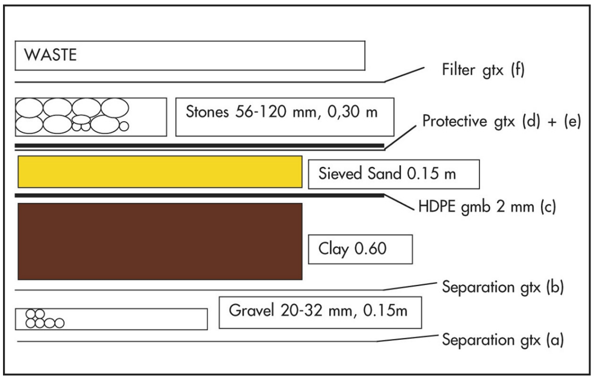

Fig. 3 and 4. Cross section of the basal granular layers and the separation geotextile being installed.

3 THE SLOPES

The slopes are steep: 1v : 2h and even up to 1v : 1.5h and have lengths of up to 70 m.

First a 600 mm thick layer of clay was placed on the slopes up to a level of 6 m above the base of the excavation and was compacted. Next, a 2 mm HDPE geomembrane (g), having spikes underneath and a smooth upper surface, was installed. Individual rolls, when placed, were welded together. As in the case of the lower membrane, hot wedge double welding was used and each seam was tested for integrity by means of an air pressure test, electric wire test or a vacuum chamber test, depending upon its situation.

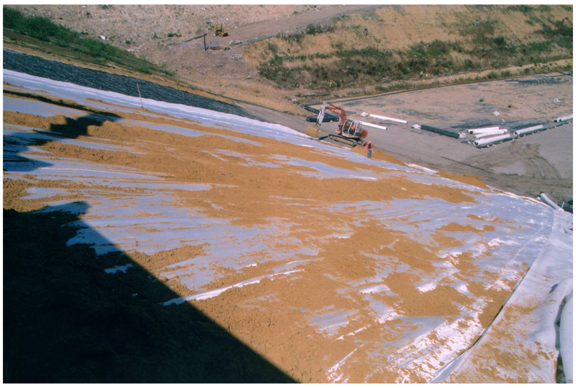

Fig. 5 and 6: Reinforcement geotextiles with tensile strength of 450 kN/m were placed on the geomembrane, anchored at the top of the slope and loaded with 0.30 m of cement-stabilised sand (5).

A composite reinforcement geotextile (A textile with a tensile strength of 450 kN/m (h) and a 200 g.s.m. nonwoven (i), stitched together) was placed on top of the geomembrane and was anchored in a trench on top of the slope. The nonwoven part of the composite was placed in direct contact with the geomembrane. On top of this a layer of sand was placed. This sand was stabilised with a percentage of cement calculated as a function of required future compression strength - which in turn depended upon the slope angle. The sand is intended to act as a protective layer for the geomembrane when the waste disposal is filled; it is dimensioned to protect against objects with sharp edges.

The reinforcement geotextile plays a temporary role as far as its strength is concerned. During execution and before the hardening of the stabilised sand, the geotextile must take the full load of the sand, gabions and construction machines working on it. The formulae used for calculating the necessary strength of the reinforcing geotextile are shown in Figure 7 following Montjoie. The safety factor for determining its ultimate strength is F = 5.0.

Another role for the 450 kN/m geotextile will be utilised later: when the site is completely filled and settlement takes place, the interface between the geomembrane and the lower part of the composite (i) will form a sliding surface. The friction between the geomembrane and the reinforcement/sliding geotextile has been selected as a minimum to avoid stresses in the geomembrane. If such a precaution is not taken, then as a result of stresses over a long period, stress cracking could occur in the geomembrane. This should be avoided. This principal of design, ‘Zero Tensile Stress in Geomembrane’ design, was developed by Hilde to improve the long-term behaviour of geomembranes in waste disposal sites. It is also very important to protect the welded seams from stress. Those seams are most susceptible to stress cracking because their ultimate strength under laboratory conditions is 70 %, but under site condition only 50% of the strength of the membrane.

To provide values of the friction coefficients between the different geosynthetics, laboratory tests were executed at the Geotrack Rapide laboratory in Leeds (U.K.) according to ASTM D5321-92.

Resultant angles of friction between the nonwoven and the reinforcement geotextile were found to be 34.2 degrees. The stitching together of the 2 layers of geotextile was found to increase the angle of friction to 39 degrees. The friction angle between the reinforcement geotextile and sand was measured at 40 degrees. Published literature indicated that the friction angle between the smooth side of the geomembrane and the underlying geotextile would be approximately 8degrees (Koerner 1998; Montjoie). In the authors’ view, results obtained under laboratory conditions should be used with care: under site conditions values can be significantly lower because of the presence of water. But it is clear that in case of settlement, sliding will occur between the smooth side of the geomembrane and the geotextiles, which are stitched together. In the case of this site, laboratory values were acceptable, because lower frictional values induced by water would be advantageous.

In practice, it is recommended that once the sand has become fully stabilised and the restraining toe weight has been constructed, the anchorage on top of the slope should be cut off to allow sliding of the geotextile whilst the waste disposal is filled and the waste volume reduces gradually due to settlement.

After the hardening of the sand, HDPE gabions, filled with rip rap, were installed on the slopes: the first 10 m over the full surface and above this level in rows which are not vertical but slanting and at a distance of 10 m between each other. The function of the gabions is to drain leachate down to the bottom of the facility, where it passes into the collection system. Unfortunately, although the gabions allow bio-gases to escape, they disadvantageously promote the infiltration of air, containing oxygen, to the waste mass. This air infiltration occurs when air inflow takes place into the facility caused by negative pressures created by the gas outflow well system.

Because oxygen mixed with methane can become an explosive mixture, it is necessary to take all possible steps to avoid air inflow. One possible solution is to put a thin geomembrane over and around the gabions. This can be removed gradually as the waste facility is filled up.

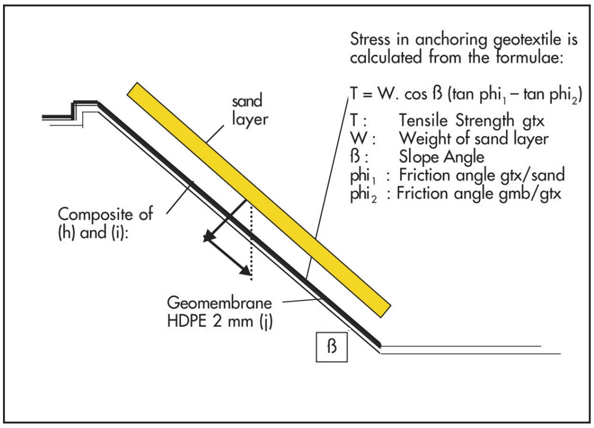

Fig. 7 and 8. Cross section of the sloping geosynthetic- and granular layers.

4 THE CAPPING

After the facility has been completely filled, a capping is to be installed in order to stop seepage of water through the waste. The capping, as used in previous projects, will consist of a 1.5 mm HDPE geomembrane (j) beneath a 600 mm thick clay layer. Above the clay and below the geomembrane are three-dimensional geocomposites. Layer (k) will be placed on top of the clay to drain off infiltrating rainwater and geocomposite (l) will be placed underneath to evacuate gases. Flows are calculated following the ‘Recommendations pour l’employe des géotextiles’. Above the upper geocomposite a root resistant geotextile (m) is to be installed to avoid the growth of roots through the geocomposite, into the clay beneath. Above this anti-root geotextile, a 600 mm thick layer of subsoil and topsoil will be spread.

From experience we know that differential settlement of waste, due to biodegradation, causes the capping to have an unforecastable final topography. In hollows which will certainly form, water will collect, increasing localised loading, thus causing more settlement.

To meet this problem, current plans are to work in two phases. The first phase will be to install a temporary capping using semi-permeable materials. Small quantities of water can percolate through the capping to feed the bio-degradation processes within the waste. This temporary capping will be designed to cope with large differential settlements.

In the second stage, when the expected settlement of 20 – 35 % of the volume of waste reaches its final stage, the final capping can be installed with a stable, engineered topography.

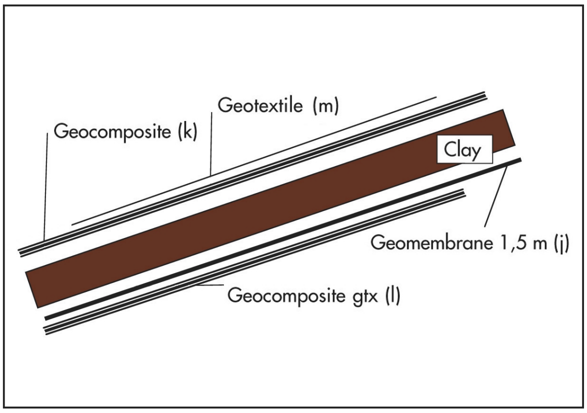

Fig. 9. A 5 m wide reinforcement geotextile failed at the top, sliding down to the base level.
Fig 10. Cross section of the capping geosynthetic and clay layers.

5 FAILURE OF A REINFORCEMENT GEOTEXTILE DURING INSTALLATION

During installation, as a result of accidental site damage at the crest, one long section of reinforcing geotextile failed by breaking at the top and sliding down to the base level, together with its overlying sand layer.

The reinforcement textile (ultimate strength of 450 kN/m), was 5m wide and was loaded with 300 mm of stabilised sand over the distance of 70m on the 1.5v : 2h slope. This gave a calculated force component of 500 kN/5 m perpendicular to the slope. The geotextile moved on top of the underlying geomembrane without damaging it.

One of the critical design features – zero tensile stress on the membrane – was proven as successful in a matter of a few seconds. The low frictional coefficient between textile and membrane became evident and the fact that the textile alone was carrying the weight of the overlying sand was also proven. This design system has been used for many years: the principle worked. The geomembrane was inspected and found to have suffered no damage. It retained perfect quality.

An original part of the design was to construct a restraining mass at the toe of the slope. This would absorb the downslope force of the stabilised sand layer on the slope. This addition safety feature had not yet been constructed when the failure took place.

Why did the reinforcing textile fail at the slope crest? Why did only one section fail? The textiles had been placed for three weeks when the accident took place. The textile itself was a strong multifilament polyester – polypropylene had been used on slopes with flatter gradients. It had been designed to cope with the construction stresses and yet one section failed.

Examination and tests on the geotextile, including the place of rupture, confirmed that they conformed to their specification and initial tensile strength. There was not any measurable reduction from the initial specification: no damage was caused during installation and, interestingly (in view of some commonly held views on alkaline attack of polyester), after 3 weeks no reduction in strength was found caused by the alkaline environment of pH 12.5 which was measured in the overlying cement-stabilised sand.

Detailed analysis of the geotextile sample at the University of Liege (Belgium) provided the answer. It was demonstrated that mechanical damage had been caused to the textile at the crest of the slope by the cable of a winch situated at the top of the slope. This winch and cable were used to support bulldozers working on the steep slope. The cable had rubbed over the geotextile at the edge of the slope and worn it and made holes in the geotextile, which initiated rupture. The influence of such limited damage on the residual tensile strength of a reinforcement geotextile will be the subject of a separate research project. There will also be follow-up research on the residual strength of these polyester geotextiles in an alkaline environment.

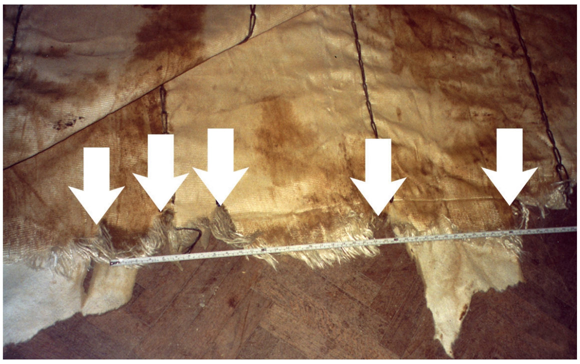

Fig. 11. The failure of the reinforcement geotextile at the top of the slope.
Fig. 12. Details of the reinforcement geotextile where at least 5 holes initiated rupture.

The broken geotextile was replaced and care was taken to avoid any mechanical damage on new geotextiles installed. No further problems occurred.

6 CONCLUSIONS

Many years of outflow testing on earlier cells from this site have permitted the authors to come to the conclusion that, using designed systems as described in this paper, it is acceptable to build new waste disposal sites in areas which are, from the geological point of view, not favourable for waste containment. Geosynthetics contribute vitally to the successful achievement of this goal.

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