Behaviour of drainage geosynthetics for landfill capping systems

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ABSTRACT: Capping systems of landfills are made used with a sequence of layers of different materials, each one having a specific function. One of these layers is mainly used as a drain, which should prevent the rainfall from reaching the waste body, thus avoiding the excess of leachate production. Drainage geocomposites are becoming an interesting alternative. This work describes the performances of a specific type of geodrain, which contains special draining tubes, at two different scales of observation: a large cell in the laboratory and a field test in a landfill.

1 GENERAL FEATURES

The use of geosynthetics is highly recommended for the construction of the capping of a landfill, in order to ensure the following functions:
- A high waterproofing grade in order to minimize the amount of rain leaking inside the volume of waste once the landfill is closed. This allows for a quicker consolidation of the waste mass over time,
- Collecting and drainage of rainfall,
- Attitude to accept differential deformability of the whole capping system, which should fit the settlement of the waste mass over time,
- The aptitude to exhaust the possible formation and pressures of biogas, and
- The possibility of growth of natural vegetation in order to reduce the visual and environmental impact of the landfill.

Considering the above points, the design of the capping structure can be arranged using only natural materials (soil with high clay content for the waterproofing layer and granular materials for the drainage) or using both natural and artificial combinations. In this paper, some test results after a comparison of the draining performances of the above mentioned geocomposite and gravel, more commonly used, are given.

The geosynthetic used for the experience is a manufactured product (Draintube FT AFITEX, Fig.1), applied on landfill capping for rainfall water drainage on the geomembrane or for gas drainage under the geomembrane. It is also used in hydraulic structures such as ponds for drainage of groundwater and gas under the geomembrane. Composed only of polypropylene, this geocomposite is chemically inert to leachate and hydrocarbons. All its components are industrially associated by needle-punching, which does not change the hydraulic properties of the geocomposite. Thanks to its composition and its mini-drains, the geocomposite has high crush and creep resistances. It is delivered in 4 m wide rolls and is unrolled in the direction of the slope and joined by welding or hot-air flame. It provides both drainage and mechanical protection of the geomembrane.

The mini-drains, positioned at regular intervals, provide collection and an oriented evacuation of water and gas. The geodrain is designed for each project according to the mechanical and hydraulic characteristics of the site.

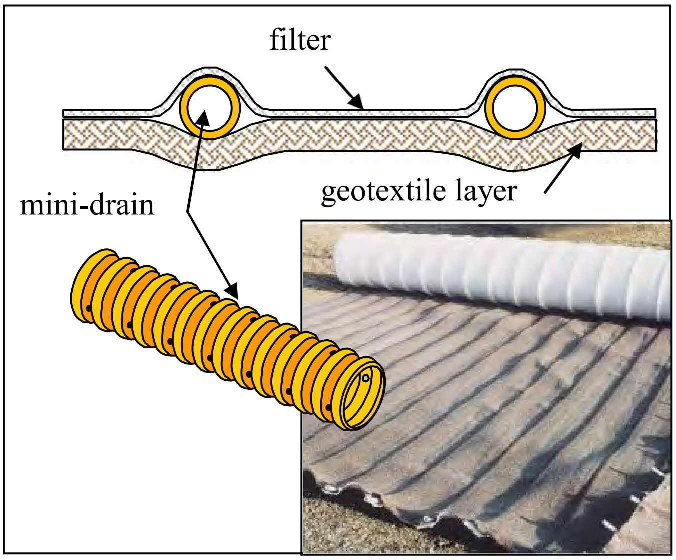

Figure 1. Scheme of the tested product

2 LABORATORY TESTS

The testing equipment consisted in a metal box, open on the top, 2.5 m long, 2 m wide and 1.2 m tall, inside which the layers of the capping were simulated (Fig.2). The metal box had a filter net in the front part, right above the drained water collecting system. In the rear part of the box a lifting device allowed to change its inclination, up to 20 degrees. The rain was simulated using 18 nozzles, placed with a regular pattern, which sprayed the water evenly from above for a period of 10 minutes in a first test series. The incoming amount of water was measured with a counter. The amount of drained water was measured using plastic bins.

The testing configurations are meant to simulate the capping structure. The configuration that involves the use of natural materials is, from the bottom to the top: a filtering geotextile, a 0.5m thick gravel layer, another geotextile and finally a 0.1m thick layer of sand. During the testing, the geocomposite was placed directly on the bottom of the cell and then covered with a 0.1m thick layer of sand. Two different models have been tested, one having the spacing between the mini-drains of 1 m (which will be referred to set 1) and the other one with a 0.5 m spacing (set 2).

Tests were performed with the cell tilted of a 5°, 10°, and 15°, in order to replicate the variety of inclinations on the capping structure. For each configuration, the testing procedure was repeated following the steps described below:

- The cell was tilted up to the desired inclination,
- The nozzles started spraying water into the cell,
- The responsiveness of the system was taken into consideration by measuring the time it took to the first drop of water to reach the collecting device,
- The rain was interrupted after 10 minutes,
- The amount of water drained from the cell was measured after 10, 15, 30, 60, 65, 70 and 80 minutes after the first drop of water was collected, and
- Before the next test could be performed, all the water had to flow out of the cell.

Figure 2. The large cell

Following the testing procedure, the first observable datum is the time required for the first drop of water drained from the different draining systems in order to reach the collecting device. According to the measured values, the draining geocomposite is more responsive than gravel, and the difference in spacing between the mini-drains has a considerable influence on the initial performance. The tests were split into time intervals, and the volume of drained water was measured according to this division. In this way the flow capacity was calculated for each time interval. Figure 3 shows the variation of capacity in time for the testing configurations, and compares their performance at different tilt angles (5°, 10° and 15°). It can be seen that the behavior of the gravel drain and of the tested geodrain with 1 m spacing (set 1) are quite similar at 5° and 10°, while the geodrain with 0.5 m spacing (set 2) exhibits a different performance, being more responsive and thus more efficient in the first minutes of testing.

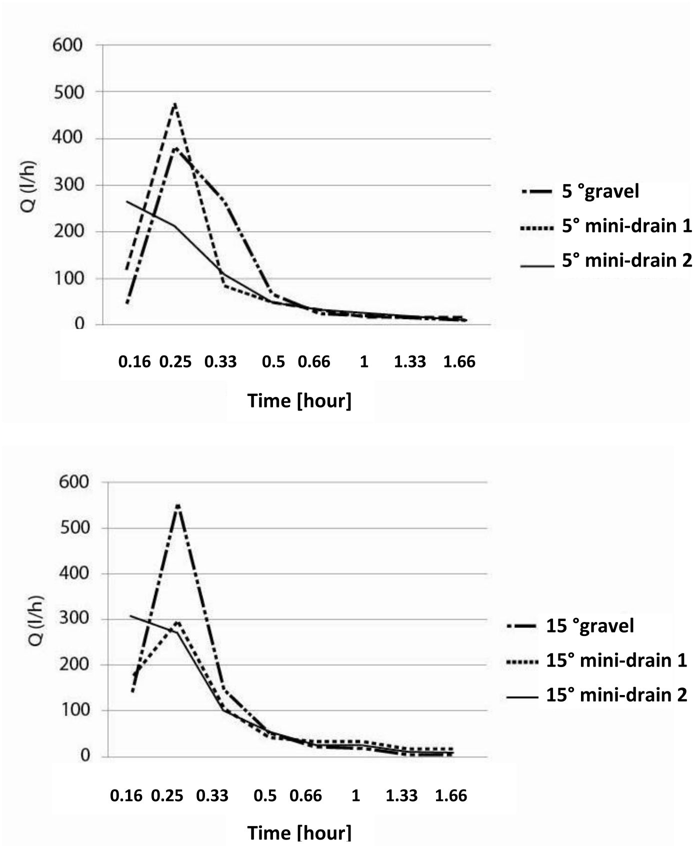

Figure 3. Comparison between the performance of the different testing configurations at 5° and 15°

The tests have also been carried out within a second series. The measured parameters related to draining attitude of the different assembled materials were:

- Irrigation flow: 2 - 3 - 4 l/min corresponding to 24 – 36 – 48 mm/h,
- Inclination of the cell, and
- Drained flow.

Tests have been carried out on two different settings of the materials, one similar to the draining layer of a landfill capping system by using natural soils, and one assembled with a geocomposite associated with geomembrane for draining purposes.

The first setting, which simulates the draining part of a traditional landfill capping, is adopting the scheme on Figure 4.

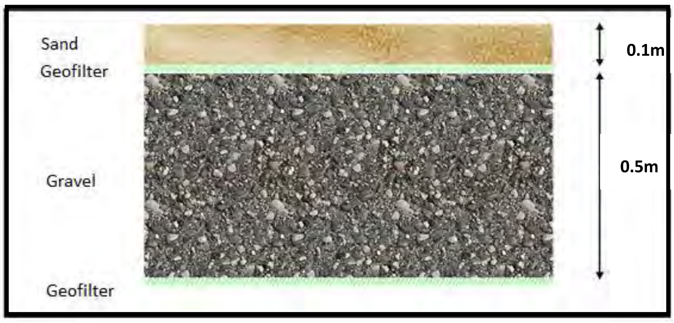

Figure 4. Setting with gravel

The second setting, which simulates the draining part of an engineered landfill capping by means of geodrains, is adopting the scheme shown on Figure 5.

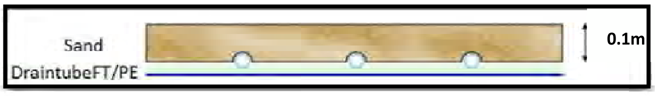

Figure 5. Setting with geodrain

The tests involving the geodrains have been carried out by changing the inclination between 2.5° to 20°, and by changing the irrigation flow.

The experiences have shown closed results between the two drainage settings (Fig. 6). It can be evidenced that at low irrigation values (2 l/min) the conventional setting allows a quicker drainage of the water volume if compared to the geodrain setting, in particular for low inclination of the cell.

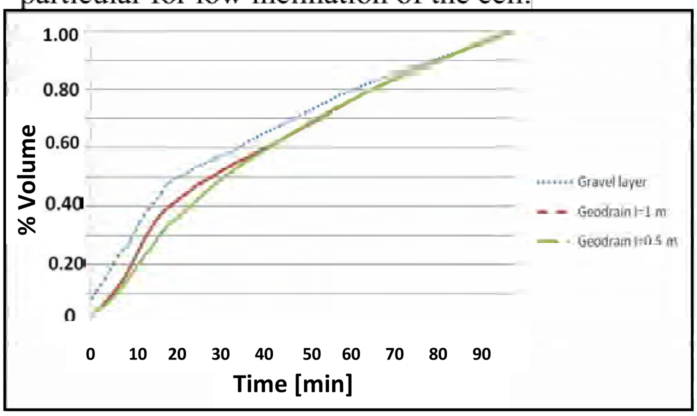

Figure 6. Comparison between different settings at low irrigation flow, at low inclination (2.5°) of the cell.

The direct observation of the behaviour of geodrains and the related results has shown that only in some tests the tubes have developed their role (such as for very low and low inclination that is 2.5° and 5°).

The graph in Figure 7 shows the results of the geodrain with the tube spacing of 0.5 m.

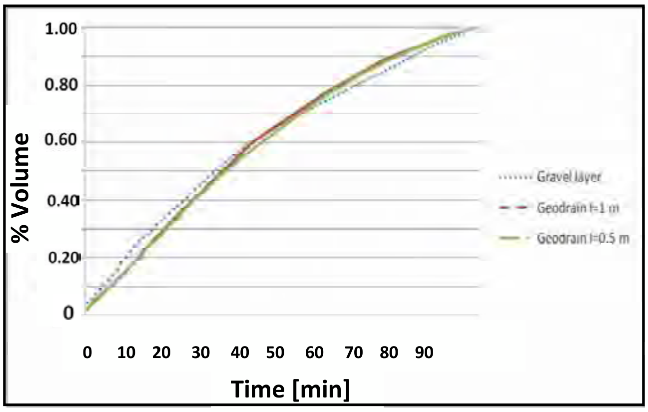

Figure 7. Comparison between different settings at low irrigation flow, at medium inclination (15°) of the cell.

The graph in Figure 8 shows the results for the geosynthetic with geomembrane, tube spacing 1 m.

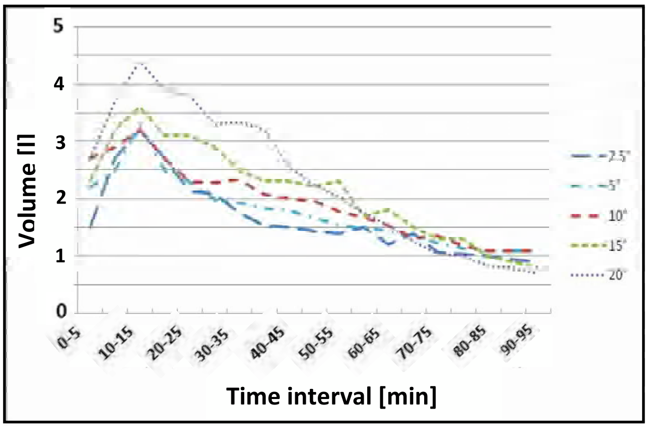

Figure 8. Comparison of drained volume during the tests, irrigation of 2 l/min,at different inclination, with tube spacing of 0.5 m

During the tests, with a low inclination (2.5°) water is coming out of the tubes: in fact there is a peak value of this configuration if compared with the previous experience.

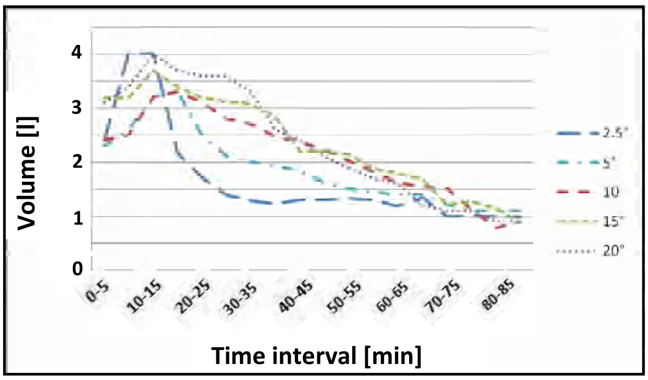

Figure 9. Comparison of drained volumes at different inclination, irrigation flow of 2 l/min, with geodrain tube spacing of 1 m

In order to understand this behaviour, tests have been carried out by increasing the irrigation flow: three values of the flow have been adopted (2 – 3 – 4 l/min) and data corresponding to flow of 2 l/m (equivalent to a rainfall of 24 mm/h) and 4 l/min (equivalent to a rainfall of 48 mm/h) are reported here. The observation has proven that the tubes start to work for low inclination and for high irrigation flow, as it is possible to see in the Figure 10 where the behaviour at 2.5° and 5° exhibits peak values higher than the behaviour at higher inclination.

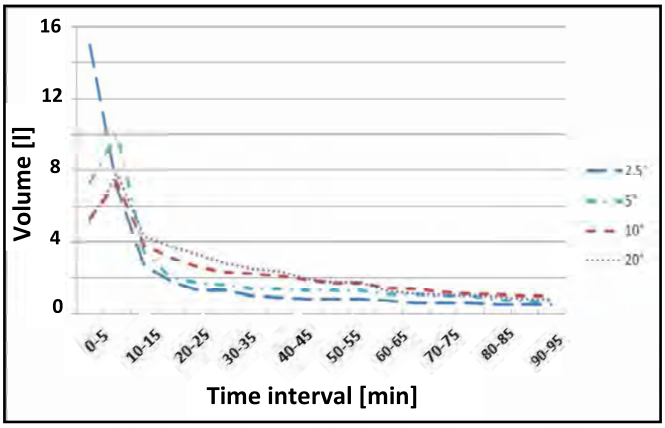

Figure 10. Comparison of drained volumes at different inclination, irrigation flow of 4 l/min, tube spacing of 1 m

In terms of speed the time for the collection of the first liter has been measured.

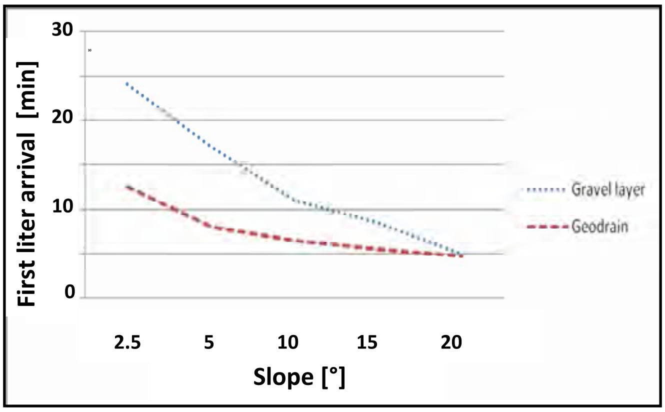

Figure 11. Comparison for the first litre arrival time

The setting with the geosynthetic has an higher promptness at low inclination compared to the gravel layer, while the difference is negligible at higher inclination.

3 FIELD TESTS

Two test fields have been arranged on a landfill site. The first simulates the traditional soil of a capping; the second adopts the geodrain system for the drainage layer. The fields are twins and they are 4 m wide and 10 m long, both laying at an inclination of 5°.
The two fields are schematized as in Figures 12 and 13. In order to get a lateral confinement, a contour with small embankments has been made for each field. A geomembrane has been installed at the base in order to provide isolation for vertical drainage towards the base ground. At the toe of the test fields a tube has been installed in order to collect all the flowing water (Fig. 14).

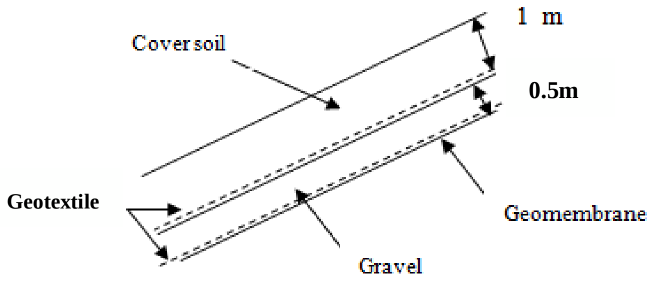

Figure 12. Setting with gravel and cover with natural soil

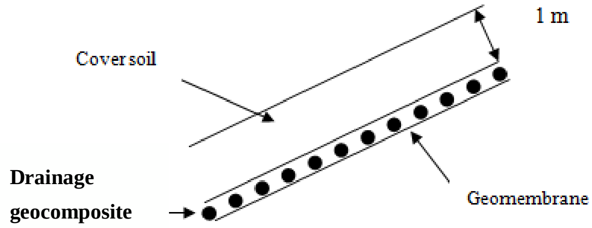

Figure 13. Setting with drainage geocomposite and cover with natural soil

The rainfall has been simulated by means of a removable irrigation system mounted on the testing area, equipped with 6 nozzles for a uniform rain. The usual rain intensity is about 25 l/min, corresponding to a rainfall at ground of 37.5 mm/h.

Figure 14. Lateral view of a field test in progress

Despite the relevant amount of water, even after 6 days of continuous irrigation, no relevant drainage has been obtained, mainly due to the natural compaction of soil and the subsequent low permeability of the material that is usually adopted for cover stratum. No piezometric level has been observed over the contact base, to confirm the long delay in saturation process and the prevalence of surface flowing of water. After this first experience the usually adopted soil has been removed and a permeable soil has been selected, in order to allow the development of a comparison between the performances of the two different setting for drainage (Fig. 15, 16 and 17).

The drainage layers have been covered by granular materials, in particular 0.25m of sand and 0.25m of gravel.

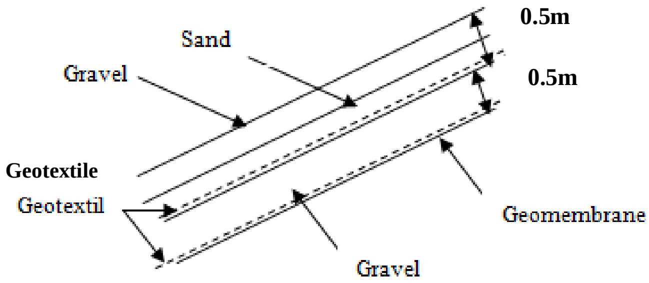

Figure 15. Setting with gravel and permeable cover material

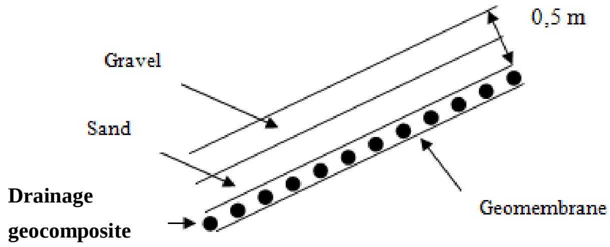

Figure 16. Setting with drainage geocomposite covered by granular material

Figure 17. Construction of test site

The most significant results are shown on Figure 18.

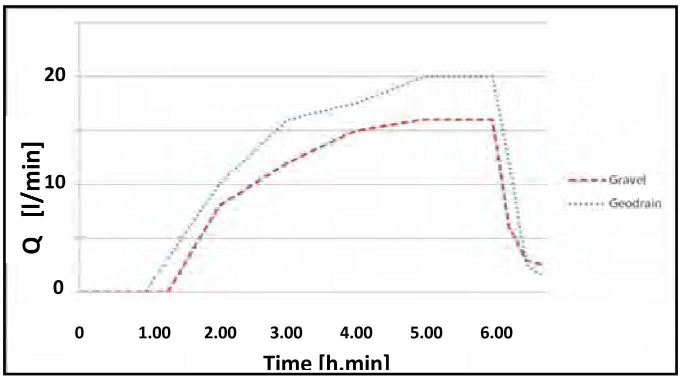

Figure 18. Site test results

The experience shows that the geodrain is able to collect water in a quicker way than the gravel. Then, the flows of drained water are increasing with a similar trend, and for the draintube system the sill value is a little higher than the gravel. After 5 hours of continuous irrigation, the drained flow becomes stable for both settings.

Tests have been repeated also with partially saturated soils. On the basis of this second experience, it was possible to observe that also in this case the geodrain setting starts to drain in a quicker way than the gravel.

4 CONCLUSIONS

The obtained results can be considered quite interesting for the understanding of drainage abilities of capping systems in landfills, both for the setting of adopted materials and also for the size of the test fields. The comparison in the cell has experienced rainfall intensity of about 24-48 mm/h, not so exceptional but anyway quite relevant. The tests in the cell have shown that the traditional system with gravel is slightly more effective as total drained volume on 1 h basetime, while the geodrain solution drains more quickly especially with a low inclination.

In the case of field tests, the promptness and effectiveness of geosynthetic alternative to traditional gravel layers for low inclination of the profile has been pointed out. The low inclination and a rainfall intensity of 37.5 mm/h have put in evidence that natural soils usually adopted do not allow a relevant migration of water down the 1.0 m thick capping layer. With higher inclination this problem can become more relevant. By using a permeable soil as cover, just for the comparison, both drainage systems are suitable, and the geodrain setting has an interesting reaction time and a short transition time.

In conclusion, the geosynthetic alternative is effective and comparable to the traditional system. It is also competitive for low inclination of the capping, when the extension of flat areas is relevant and long term settlement can determine low inclination of cover systems and consequent presence of water at surface.

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