Large scale field trial in a landfill cover system with veneer reinforcement

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ABSTRACT
Landfill cover systems are often composed of the succession of different soils and geosynthetics serving specific functions. When the systems are laid on slopes, high tensile forces are generated by the weight of the top soil that tends to move the system downwards. The use of high strength geogrids is nowadays a well-established technology that enables the safe construction of such slopes and limit the tensile force transfer to the sealing system.
To better investigate the behavior of the geogrid in such conditions, a field trial was carried out in a municipal solid waste (MSW) landfill cover system with geosynthetics. In the large scale trial, the geogrid behavior was analyzed in terms of deformation during different phases: installation, monitoring and controlled failure. Different displacement transducers were installed in the geogrid along the slope length and the anchor trench. The system was continuously monitored during one month after construction and after that it was brought to a controlled failure.
In this paper, the setup of the field trial and the preliminary results during installation, monitoring and failure of the system are presented and discussed.

1. INTRODUCTION

Multi-barrier systems composed of soil and geosynthetic materials are the current technology adopted to design modern landfills (Shukla and Yin, 2006). Geosynthetics are usually used in this application to handle specific functions such as sealing, reinforcement, filtration, drainage, protection, separation and erosion control (Giroud, 2012). As the geocomposite systems are usually laid on slopes, even steep slopes, the weight of the cover soil above induces a destabilizing force moving the system downward (Jones and Dixon, 1998). Therefore, the overall integrity of these systems is primarily linked to the sliding along the slope at the interfaces (Carbone et al. 2015; Eid, 2011; Palmeira et al., 2002). In this case, the use of the geogrid reinforcement assures equilibrium of forces (Carbone et al., 2016; Lavasan et al., 2016). The behaviour of such geogrid materials has been assessed through laboratory tests (i.e., tensile strength, pull-out and shear box tests) and several mathematical models to reproduce the load transfer mechanism between the geogrid and the surrounding soil (Russo, 2008). However, there is still little information on the in situ performance of geosynthetic liner systems on slope. Although, in-service failure can lead to environmental damage, commonly used design approaches have not been verified through monitoring of liner behavior during construction, filling and after closure. A large measurement campaign was therefore carried out during a field test at the “Torretta di Legnago (Italy)” landfill secondary cover system. This paper describes the test field set up and presents the first preliminary results.

2. “TORRETTA” LANDFILL IN SITU FIELD TEST

2.1 General background

The “Torretta” landfill (Fig.1) is a municipal waste landfill located in Legnago (Verona, Italy) operating since 1982. In 2003, the cells A and B, having reached their maximum capacity, were closed with a cover system consisting of different mineral layers in accordance with the regulation in force at that time. However, after some years, the mineral barrier of 30 cm of clay showed some cracks which resulted in an increase of leachate production due to the rainfall infiltration into the landfill body of approximate 20% of the precipitation water. This implied a significant rise in the cost of leachate treatment, which the owner is required to take charge for a period of 30 years after closure.
To overcome this problem in 2015, it was decided to install a secondary geosynthetic lining system providing the landfill with a reliable long-term sealing solution.

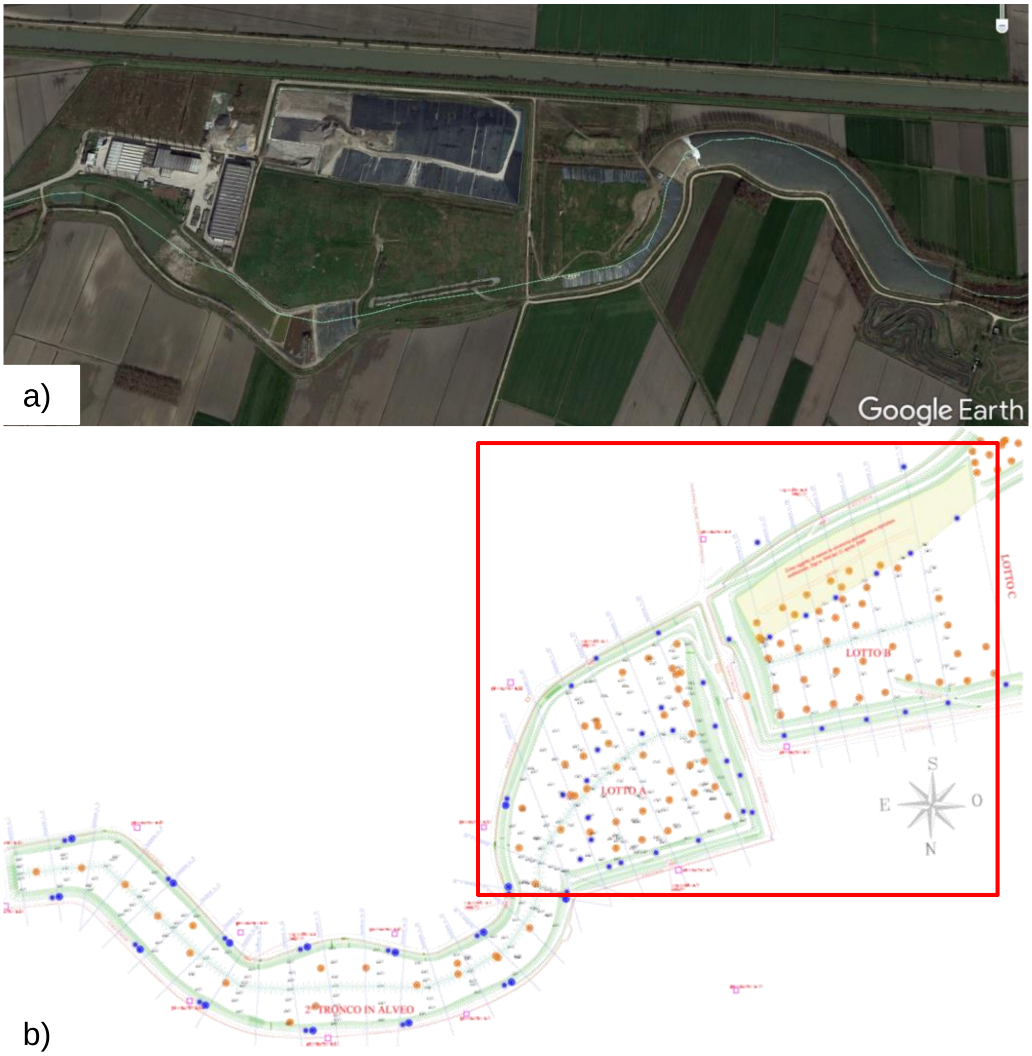

Figure 1. “Torretta” landfill: a) aerial view (Google Earth - March 2018); b) top view

Prior to the installation, the sustainability and serviceability of the secondary geosynthetic lining system was proven by means of a field test. The field test aimed at investigating the behavior of the geosynthetic liner system under in situ conditions and in particular during installation, operational and under induced failure phases.
During the test were analyzed:

- the geogrid deformations along the slope and in the anchor trench
- the in-situ acting stresses (earth pressures)
- the geogrid gripping capacity in contact with the geocomposite drain.

The project was jointly planned and implemented by the University of Padua, the designer and supervisor engineer Busana, the landfill owner Le.Se. (Legnago Servizi) and HUESKER research center and engineering department.

2.2 Field test description: materials and main phases

The new lining system consisted of a geomembrane, a geocomposite drainage and a high-strength geogrid covered by 80 cm of topsoil.
Table 1 summarizes the main properties of the materials used for the field trial.

Table 1. Principal properties of the materials used for the Torretta landfill field trial.

Material	Function	Thickness	Description
Geomembrane (GMB)	Sealing	0,6 mm	woven HDPE fabric laminated with LDPE – tarpaulin type
Geocomposite Drain (GCD)	Drainage	4 mm	Cuspated reticular HDPE drainage core laminated between one or two layers of non-woven geotextiles
Geogrid (GR)	Reinforcement	1 mm	Flexible PET geogrid with polymer coating and nominal tensile strength of 55 kN/m in machine direction
Top soil	Covering/greening	800 mm	Silty-clay soil characterized by the following mechanical characteristics: ϕ' = 26° and c'= 9 kPa

The field trial was carried out in a specific section of the landfill that represented the in-situ worst case section with a slope inclination equal to 34°. The slope length was equal to 11 m and the geosynthetics were installed along a total width of 3,3m. The geosynthetic layers were fixed through an anchor trench which length was extended for the experimentation purposes. At the toe of the slope, four removable blocks where installed in order to test the passive force influence on the slope stability.
The schematic cross section of the field trial is shown in Fig. 2.

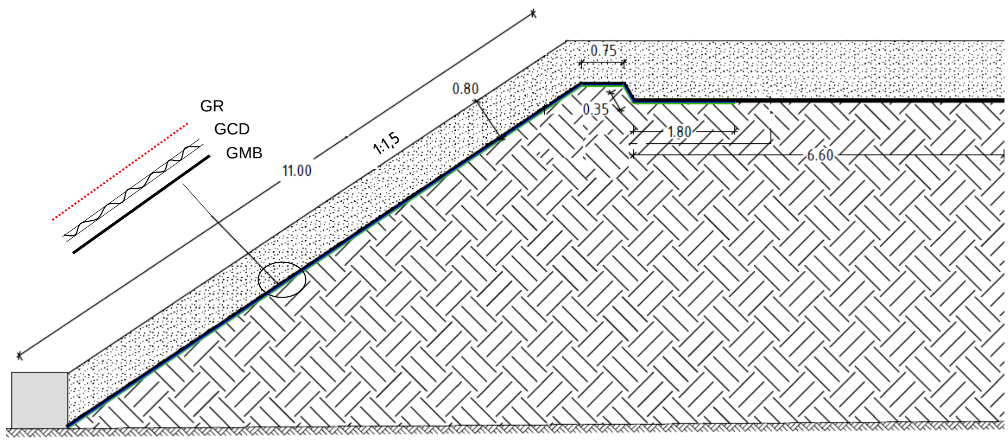

Figure 2. Cross section of the Torretta landfill field trial

The field trial consisted in three main phases:
1. *Installation phase*: slope preparation (cleaning and levelling the subgrade); materials (i.e., geosynthetics and top soil) installation and sensors installation and calibration;
2. *Monitoring phase*: the data of the displacement transducers and the pressure cells were collected during one month after installation;
3. *Induced failure phase*: the system was brought to failure by cutting the geogrid on the crest of the slope.

After levelling the existing surface, the first step was to locate three pressure cells into the soil where the highest variation of pressure were expected to occur. Afterwards, the geomembrane was installed on top of the clay layer of the old existing capping. The drainage geocomposite was placed on top of the geomembrane and finally the flexible, high strength geogrid was installed on top of the geocomposite drain. The geomembrane, thanks to its sealing function, limits the water infiltration into the waste body and consequently reduces the amount of the leachate production. The drainage geocomposite drains properly the infiltrated rainfall water and finally the geogrid secures the stability of the slope against sliding by taking the tensile loads acting and transferring them to the anchorage at the top. Furthermore, the geogrid was equipped with 10 displacement transducers connected to a data logger and to a data acquisition system that recorded the geogrid displacements during the different phases of the field trial. This enabled a closer analysis of the activated tensile strength along the slope and in the anchor trench. A steel bar was also fixed to the geogrid in order to distribute homogenously the load on the entire geogrid width during the induced failure phase. Fig. 3 shows the layout of the materials used in the field test.

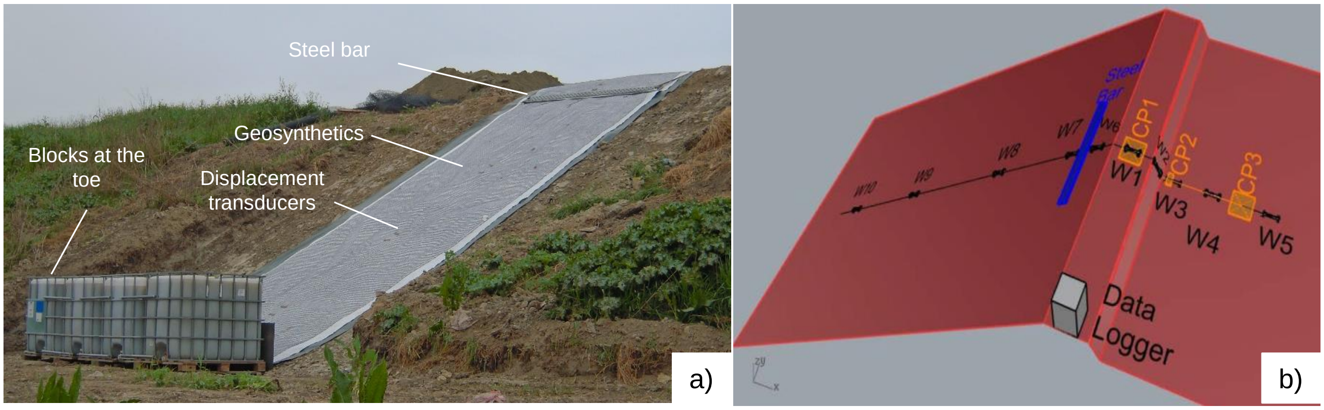

Figure 3. Torretta landfill field trial: a) geosynthetic layers, removable blocks at the toe of the slope, displacement transducers and pressure cells and steel bar; b) location of the displacement transducers and pressure cells.

3. PRELIMINARY TEST RESULTS

Fig. 4 shows the trend of the mobilized geogrid tensile strain along the slope and in the anchor trench resulting from the installation phase and the monitoring phase of approximately one month. The measurement data were recorded by a data logger as well as a data acquisition system designed for measurements in the dynamic range. As expected, most of geogrid deformation developed during the construction phase. In this specific case, the tensile loads at the top of the slope resulted in total maximum strain in the reinforcement of approximately 3% that just slightly increased during the one month of monitoring phase due to creep processes. The strains recorded in the anchorage trench were likewise registered during the construction phase and after one month, the deformation remained almost constant.

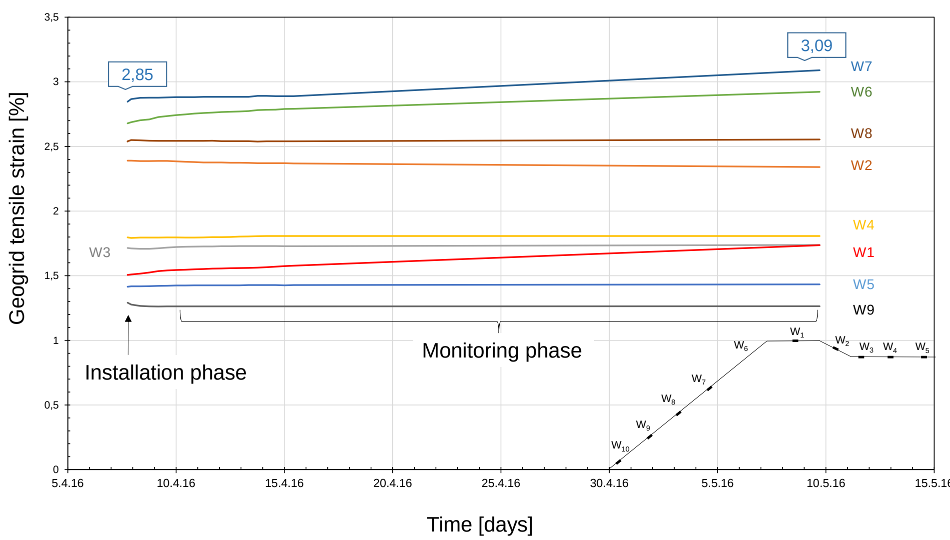

Figure 4. Geogrid tensile strain recorded by the displacement transducers during installation and 1 month monitoring phase along the slope and in the anchor trench.

Afterwards, the system was induced to a controlled failure to study the behaviour of the system also in this condition. For this purpose, at the top of the slope a portion of the cover soil was removed and the geogrid was cut simultaneously from both sides to leave a final resisting cross-section of only 68 cm (Fig. 5).

Figure 5. Induced failure phase: a) removal of the soil on top of the slope and; b) impression of the resisting cross-section after the cut of the geogrid.

Given that the geogrid had originally been 3.3 metres wide, this represented a five-fold increase in the load level acting on the geogrid, which, after a time lag, ultimately led to failure of the reinforcement and consequently of the entire system.

During the controlled failure process the soil behaved as a rigid body complying with the main assumption done in the design applying the limit equilibrium method. The geogrid used, due to its high interaction flexibility, could guarantee an optimum bond and interlocking with the soil on top and with the geocomposite drain used. Therefore, the critical interface laid between the geocomposite drain and the geomembrane as assumed in the design phase.

Preliminary test results show that by cutting partially the geogrid two main failure mechanisms were activated:

- the load level acting on the geogrid in the anchorage significantly increased, until the geogrid's creep rupture strength was reached;
- the deformation induced to the system, due to the increased loads, resulted in the mobilization of the interface friction angle at large displacement (i.e., reduced value) in the critical sliding surface.

4. CONCLUSIONS

The geogrid reinforcement plays a crucial role in geosynthetic cover lining systems. It carries and transfers the tensile forces coming from the top soil layer to the anchorage at the crest of the slope and thereby guarantees the stability of the slope. The geogrid behavior is usually analyzed by laboratory tests while there is still little knowledge about its real behavior under in-situ conditions.
In this paper, the set up and the preliminary results of the Torretta di Legnago landfill field trial is described. The preliminary results show that the role of the geogrid is relevant to secure the stability of the slope and to limit the tensile strength transfer into the other geosynthetic layers, with particular regard to the lining system which integrity must be protected against unacceptable deformations.
Upon completion of the field test, the geosynthetic lining system was successfully installed and the Torretta landfill has now a reliable long-term sealing system.
The further results analysis and interpretation is currently carried out by the DICEA Department of the University of Padua. Furthermore, a numerical model is developed and it will be calibrated by the measured data.

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