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Laboratorial Prototype for Detection of Defects on Geomembranes - The Geophysical Approach

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SUMMARY

Although there are some test methods do detect and locate defects in geomembrane liners after the placement of the primary leachate collection system, namely the soil-covered geomembrane method (mobile probe) and the grid method (permanent), the existing methods present some disadvantages. They are labor and time consuming and, so, very expensive. These conditions lead us to the development of a quick and low-cost, but also accurate, test prototype to check the geomembranes integrity after the placement of the granular layer. The methodology consists in the development of a prototype combining the mobile probe method with the multicables resistivity equipments presently used for geophysical surveys. This prototype is endowed with ways that allow to the semi-automatic data acquisition (detection location of the defects) and its processing in real time. The functionality of the prototype is presently being verified in a pilot plant, at one of ISEL's (Instituto Superior de Engenharia de Lisboa) laboratory. The experimental work under way includes different types of lining systems and defects. A bigger scale pilot plant is being constructed at LNEC's (Laboratório Nacional de Engenharia Civil) campus, to verify, at real scale, its functionality. Afterwards, the prototype will be checked in situ, at a true landfill.

Introduction

Landfills are engineering facilities designed and constructed with a barrier system (lining system) intending to assure the protection of the environment. This system includes active and passive barriers. The passive barrier comprises a compacted clay liner (CCL) and/or a geosynthetic clay liner (GCL), while the active barrier includes a geomembrane (GM), protected by a geotextile (GTX), and a drainage layer known as primary leachate collection system (PLCS). The effectiveness of lining systems in service conditions depends, above all, of the performance of GM. A critical issue on their performance is the defects, which, unfortunately, seems to be unavoidable (Nosko and Touze-Foltz 2000; Peggs 1996; Peggs and Wallance 2008; Rollin et al. 2004; Rollin et al. 2002). Most of these appear during the placement of the PLCS (Barroso et al. 2007; Colucci and Lavagnolo 1995). Indeed, data reported by Nosko and Touze-Foltz (2000), collected at more than 300 sites, from 16 countries, showed that 71% of the damages were caused by stones during PLCS installation. Also according to these authors, the number of defects per hectare is about 12.9, whereas Rollin et al. (2002) refers a value of 17.4 defects/ha. It should be noted that these values concern to GMs installed under a strict Construction Quality Assurance (CQA) programmes. Higher values can be expected in landfills without CQA

Although there are some test methods do detect and locate defects in GM liners after the placement of the PLCS, as stated by Beck et al. (2008), namely the soil-covered GM method (mobile probe) and the grid method (permanent), the existing methods present some disadvantages. They are labor and time consuming and, so, very expensive. These conditions lead us to the development of a quick and low-cost, but also accurate, test prototype to check the GMs integrity after the placement of the granular layer.

The methodology consists in the development of a prototype combining the mobile probe method (ASTM D7007) with the multicables resistivity equipments presently used for geophysical surveys. This prototype is endowed with ways that allow to the semi-automatic data acquisition (detection location of the defects) and its processing in real time. The functionality of the prototype is presently being verified in a pilot plant, at one of ISEL's laboratory. The experimental work under way includes different types of lining systems and defects. A bigger scale pilot plant is being constructed at LNEC's *campus*, to verify, at real scale, its functionality. Afterwards, the prototype will be checked *in situ*, at a true landfill.

In this paper the prototype development is presented under the geophysical scope of view. Some limitations, drawbacks and results are presented. Test methodology and its results are presented by Lopes et al. (2011).

Liner integrity survey and assessment

The mobile probe liner integrity survey method (Figure 1) uses two pairs of electrodes, one (fixed) for power injection and the other mounted on a mobile unit which is used to survey point by point all the basement of the pilot plant. In a uniform medium while the mobile probe gets away from the injection point the voltage measured must drop as the potential decreases with distance, but if it raises this is a sign of the presence of a near hole/defect (Figure 2).

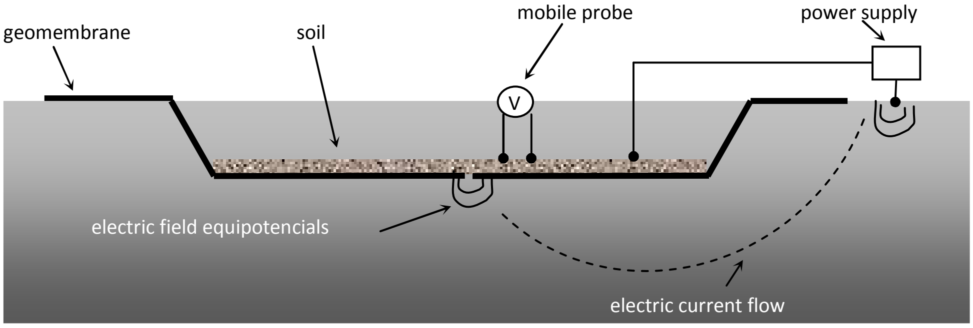

Figure 1 *Mobile probe line integrity survey method.*

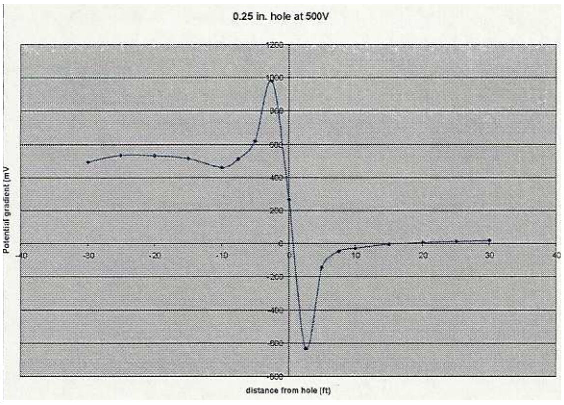

Figure 2 *Electrical potential variation near a hole/defect (Peggs and Beck 2010).*

The prototype

A prototype to detect and locate defects in GMs was constructed to work on the laboratory. It consists of a mobile semi-automatic apparatus, with a bar, where several electrodes are assembled (Figure 3) in order to measure the electrical potential, induced by the electrical current injected into the soil and into the GM cover with two far electrodes. The apparatus moves along lines across the pilot plant, and the measurements are carried out between pairs of electrodes (dipoles) along several parallel profiles in each of these lines.

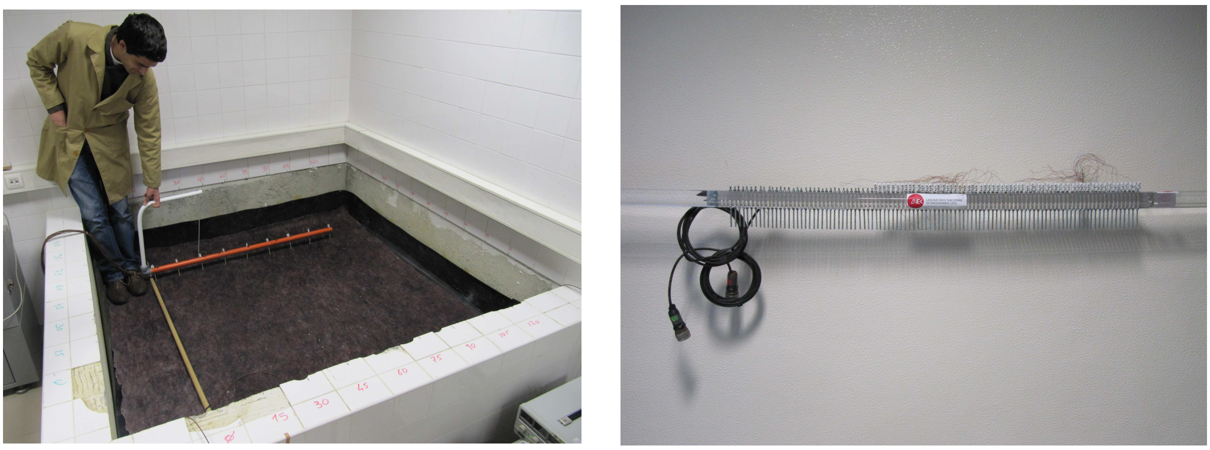

Figure 3 *Left – 8 dipoles array with dipole distances of 0.15 m. Right – Array with 0.01 m dipole distances.*

To inject current and to carry out the measurements an ABEM SAS4000 resistivimeter was used. Electrical potentials are simultaneously measured at four different dipoles. To double-check the results, measurements are performed both with the resistivimeter and with a power source and a multimeter. With the resistivimeter a constant value of current is applied between the two injection electrodes, while with the power source a constant tension is used.

Several arrays were developed and tested using the same principle of a four electrodes array used in geophysical resistivity methods: a fixed pair of electrodes for current injection, one above the lining system and the other outside of it, and a pair of reading electrodes. The difference here is the ability to perform simultaneous readings with the four channels of the resistivimeter at four different dipoles of equally spaced electrodes mounted on a bar.

A graphical interface was developed in order to control the resistivimeter and to immediately display the results (Figure 4). Simultaneously, reading coordinates, current and potential are gathered in a database to produce a full report with defects locations.

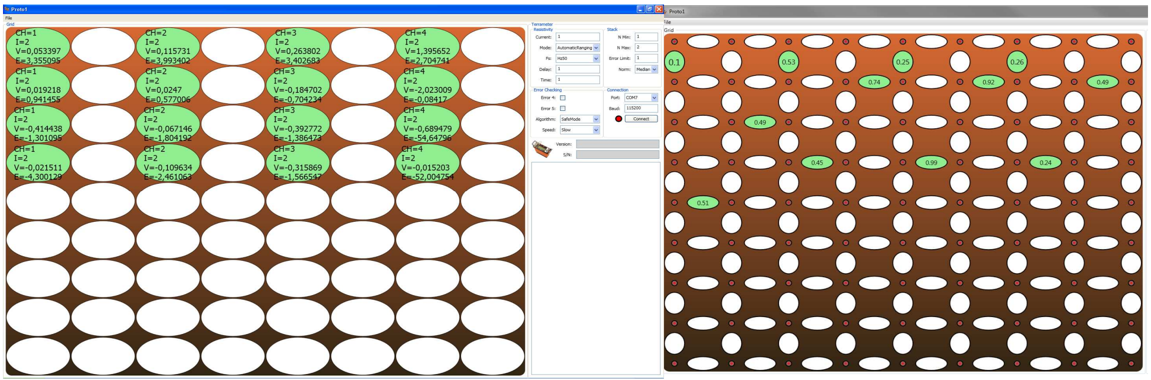

__Figure 4__: Graphical interface. Left – Example with measurements in only one direction. Right - Crossed measurements.

In the first pilot plant, developed at laboratory (ISEL), on small-scale (1.80 m x 1.80 m x 0.75 m), materials in contact with the GM and their moisture contents were changed and defects of different size and shape were made in the GM, at known places (see Figure 5, for an example). The purpose of this approach is to study the feasibility of the prototype, in a preliminary version, as well as to check the prototype's resolution (minimum size of the defects that it is able to detect) and accuracy (degree of closeness of the measurements to its actual location. Details on these tests can be found on Lopes et al. (2011).

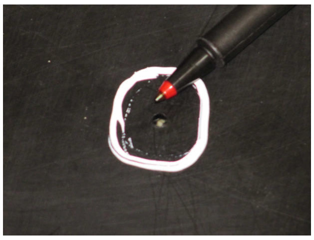

***Figure 5:** Example of a 2 mm hole.*

Results

Results obtained with both equipments of injection and measurements are presented in Figure 6. This test was performed with only a wet GTX covering a GM. Two defects with a diameter of 2 mm, 0,72 m apart, were made on the GM. Comparing both results it can be seen that there is a good match between them, although with the multimeter the values are a little higher. This is due to the dryer condition of the GTX when the resistivimeter was used and to the different principles of work of both equipments. The moisture content of the basement and of the covering material is crucial specially when using the resistivimeter. A defect situated near the source electrode installed inside the covering layer can not be identified, so it must be moved far from the reading dipoles.

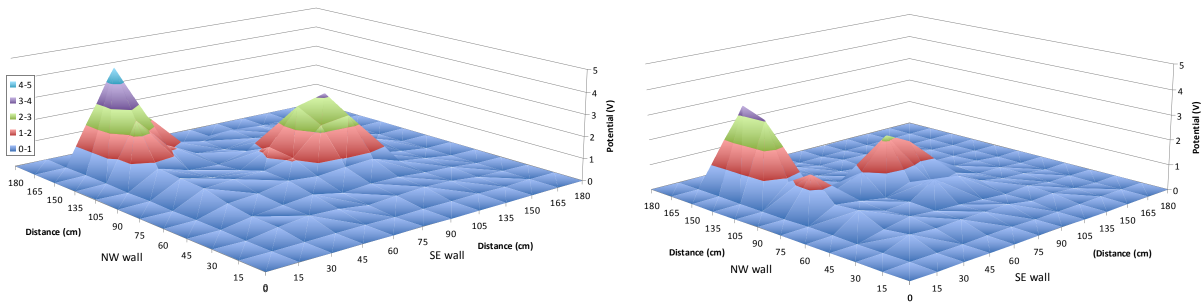

***Figure 6:** Example of results obtained with two holes of 2 mm. Left – Measurements performed with a multimeter and a independent DC power supply (60 V). Right – Measurements performed with the resistivimeter which was injecting 2 or 5 mA.*

Conclusions

Results obtained so far with the developed laboratory scale prototype are consistent and encouraging. With this method, all data is recorded, which allows to assure that basement was all covered on each survey, not relying only on the skills of the operator. The prototype seems to give accurate location of the defects. These facts leads to good perspectives for application of it on site allowing a higher use of liner integrity surveys and assessments as part of the Quality Control program of a landfill construction, which, in the end, benefits the environment.

Acknowledgements

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