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Semi-automatic Mobile Equipment Test for Detecting Holes in Geomembranes – the Prototypes Evolution

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SUMMARY

Landfills contain basal lining systems that include composite liners, among which a geomembrane (GM). The success of these systems depends mainly on the GM performance, which acts as the primary barrier to contaminants migration. GM performance is conditioned by the presence of holes, which represent preferential pathways for leachate migration. An equipment was developed to detect holes in geomembranes. It is based on the geophysical resistivity method and aims to overcome the main disadvantages of the existing methods for GM holes detection, mainly time spent to perform the tests and the associated high costs. Several prototypes were already developed and were tested at small scale in laboratory. The final version, which is the model for the equipment under construction, was already successfully tested at laboratory small scale pilot plant and in a large pilot plant at Laboratório Nacional de Engenharia Civil, I.P. (LNEC) campus. This paper presents the prototypes development and results so far obtained.

Introduction

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Equipment development

An equipment was developed based on the manual mobile reading dipole described in ASTM D7007. In the first phase of the equipment development, several prototypes were built (Figure 1), which consisted primarily of bars where the electrical potential reading electrodes were installed with fixed distances (Mota et al. 2011).

Manual mobile reading dipole has typically a 1 m dipole distance. When a hole is detected it is necessary to evaluate it with short advances around that position to reduce the uncertainty in the location of the hole.

This reading procedure cannot be reproduced with a semi-automatic system. To overcome this difficulty the first prototype (Figure 1A) had 101 electrodes 1 cm apart. It was found that it was not accurate. So, a second prototype with 8 dipoles with dipole distance of 15 cm was developed (Figure 1B). The second prototype presented a better performance, in spite of its fragile structure. With the knowledge gathered, a more robust prototype was built. It contained 20 dipoles spread over 1 m and with smaller dipolar distances – 5 cm – which allowed the use of multiple distances - 10, 15, 20 and 30 cm (Figure 1C). Results obtained with the third prototype showed that it is possible to use the semiautomatic equipment with a dipole arrangement of the same order of magnitude of the manual dipole mobile reading and, upon detection of a hole, tighten the reading mesh to better locate it. Since the 30 cm dipole distance produced accurate results and proved to be the most appropriate arrangement, it was decided to build a new prototype in a 4 × 4 dipole mesh with 30 cm dipole distance (Figure 1D).

This arrangement of electrodes (16 electrodes) is a base 2 number allowing a modular construction of the controlling embedded data acquisition system (Matutino et al. 2011). This arrangement is also suitable for a 1 m × 1 m modular construction of the equipment.

For a quicker survey and less movements in the landfill cell the equipment will have 4 interconnecting modules of 1 m × 1m. This allows spending less time settling the equipment in the beginning of each survey, since there are only some connections to assemble, and each module fits in a commercial van.

This electrode arrangement allows surveying 4.5 m^2 – the modules are fixed with a distance between them that allows maintaining the dipole distance in all the 64 electrodes. The electrode modules can be assembled in a square arrangement or in a side by side arrangement (Figure 2). When comparing the surveyed area with that covered by the manual mobile reading dipole it can be seen that the square arrangement covers an area higher than that surveyed with 6 positions of the manual dipole, while the second one is higher than that surveyed with 8 positions of the manual dipole.

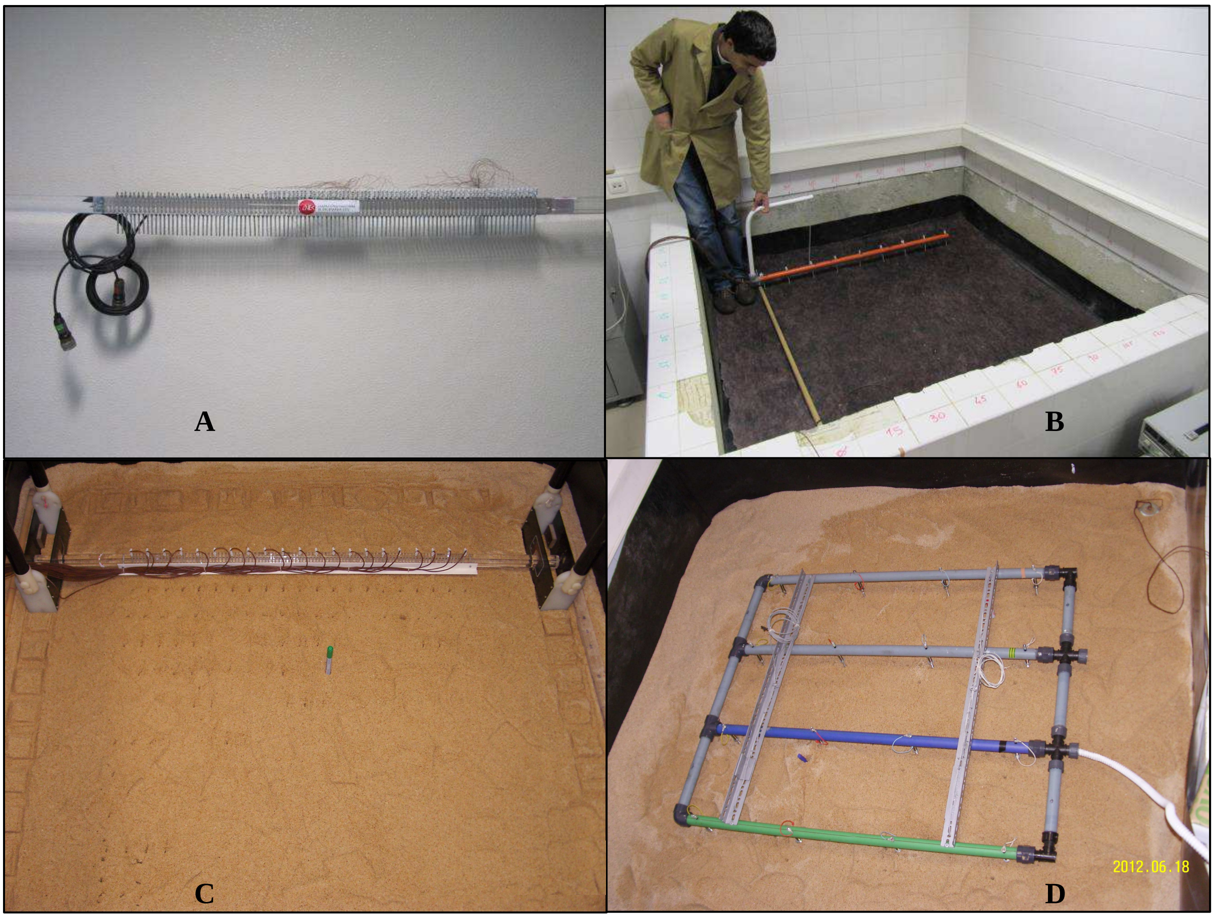

Figure 1 *Prototypes.* ***A*** *– dipole spacing = 1 cm;* ***B*** *– dipole spacing = 15 cm;* ***C*** *– dipole spacing = 5 cm (the green pen marks the hole position);* ***D*** *– dipole spacing = 30 cm (the blue pen marks the hole position).*

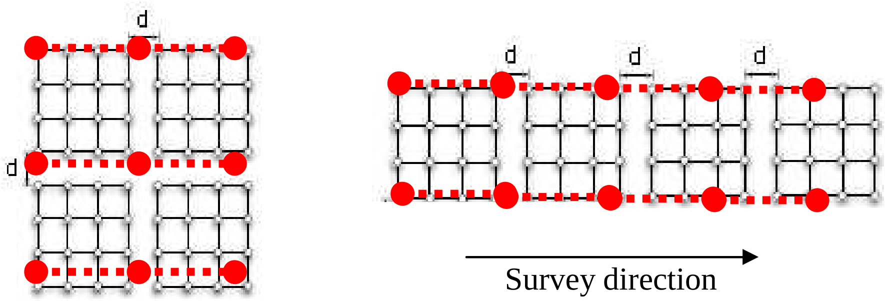

Figure 2 *Electrode modules arrangement (in red the manual reading dipole positions).* ***Left*** *– square arrangement.* ***Right*** *– side by side arrangement.*

The equipment has also a Global Navigation Satellite System (GNSS), with centimetre precision and real time kinematic positioning. The final prototype which is the model for the equipment under construction is presented in Figure 3. This prototype has stainless rod electrodes and small wheels, while the equipment under constructions has larger wheels (50 cm of diameter) and copper electrodes.

Electrical potential gradient data is stored in a database along with each dipole coordinates, allowing mapping production. In the electrical potential map all the identified holes are depicted to a quick visualization. A report with the coordinates of all holes is also produced, for an easy identification of the areas to be repaired.

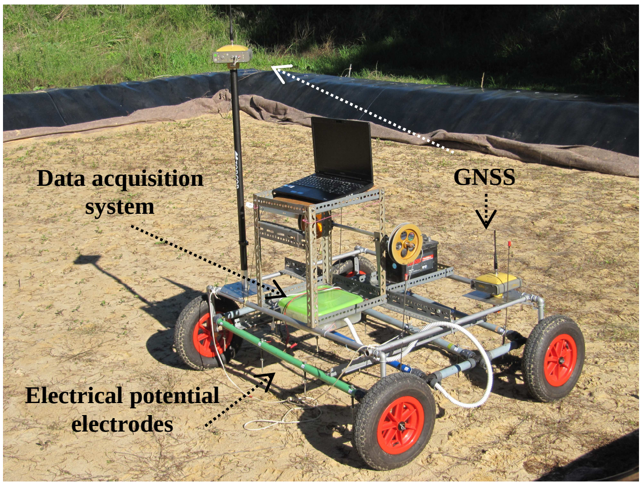

Figure 3 *The final prototype.*

Tests results

As mentioned, validation tests of each prototype were performed under controlled conditions (in laboratory). Figure 4 illustrates the results obtained with the final mesh of electrodes both at the laboratory, in a confined space (1.8 × 1.8 m (Mota et al. 2011)), where the electrical output of the source was limited to 60 V and the GM defect was a 4 cm cut, and at the large scale pilot plant (8.5 × 8.5 m) built at LNEC's *campus* with a 2 mm hole diameter and an output source of 200 V.

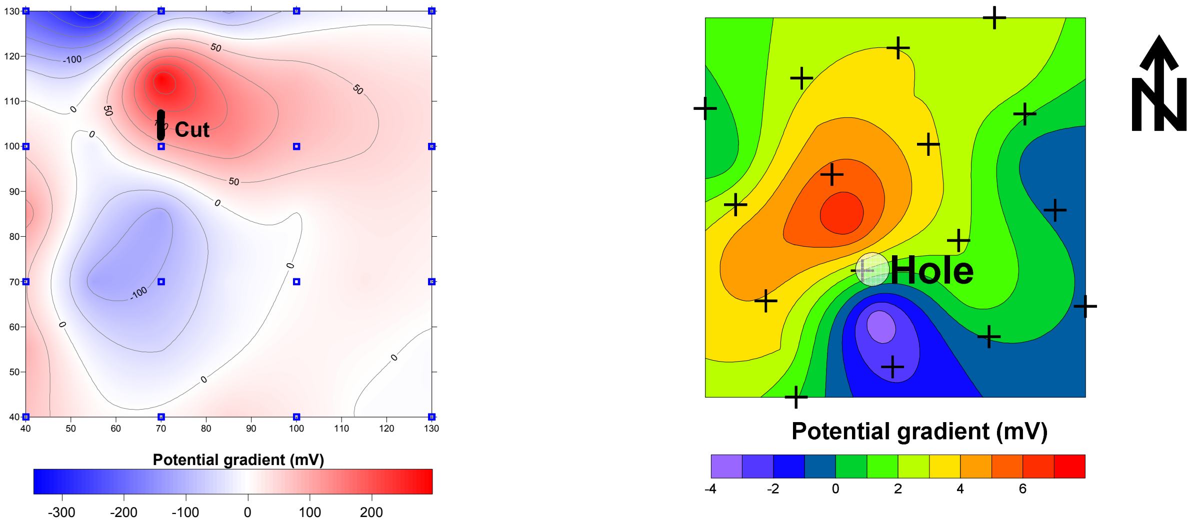

Figure 4 Left *- Prototype validation at the laboratory pilot plant (1.8 × 1.8 m – output voltage of 60 V).* ***Right*** *– Prototype validation at the large scale pilot plant (8.5 × 8.5 m – output voltage of 200 V) with the prototype immobilized over a 2 mm hole.*

The higher values of the electrical potential field at laboratory when compared to those obtained at LNEC's pilot plant is a result of the combined effect of the confined pilot plant at the laboratory and the dimension of the cut. With a hole of 2 mm at the laboratory the maximum absolute values were around 4 mV with the same output voltage and without the covering sand layer (Mota et al. 2011). With the covering sand layer the maximum absolute values was higher than 0.45 mV (Mota et al. 2012).

The following figure illustrates the results of a survey performed over the total area of the pilot plant at LNEC's campus where it is clearly identified the deliberate hole made in the geomembrane.

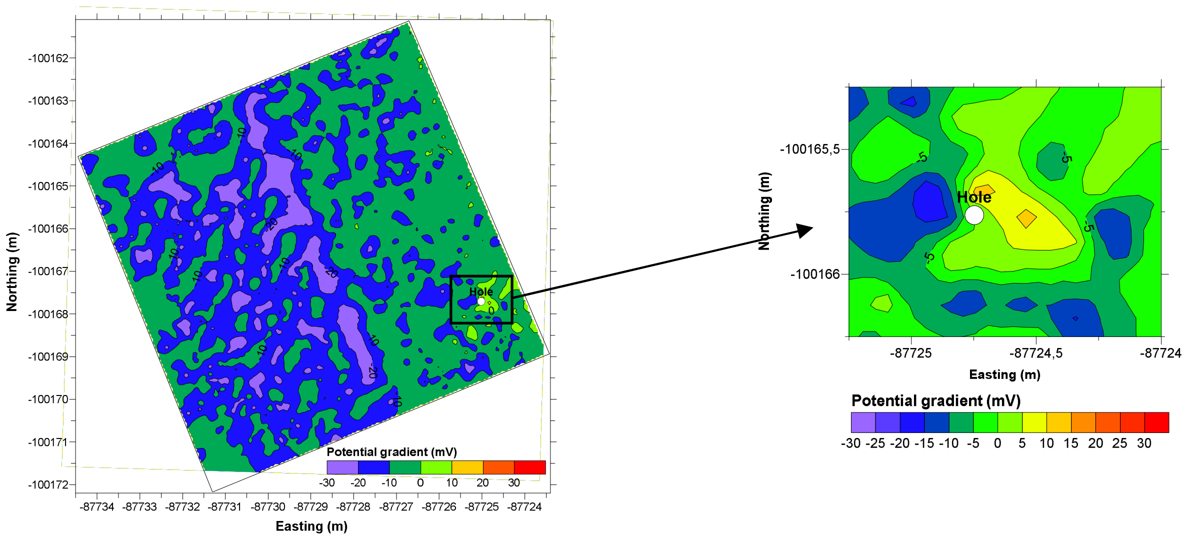

Figure 5 *Potential gradient map of the electrical field over all the pilot plant with an output source voltage of 600 V.*

Conclusions

This paper presented experimental work performed to identify and overcome the potential drawbacks of the prototype to detect and locate holes in geomembrane, before producing test equipment to be used in landfills.

Problems found in the prototypes were addressed, and a final version was constructed.

Results obtained showed that the final version of the prototype has been able to detect and accurately locate the defects deliberately made in the geomembrane.

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