THE BOUNDARY CONDITIONS OF THE ELECTRICAL MONITORING SYSTEMS IN PRACTICE

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ABSTRACT: The need and use of electrical monitoring systems for damage detection and leak location are considerably growing. Electrical monitoring systems have now been available for many years in several countries. The electrical monitoring systems were developed to control integrity of geomembranes in situ after installation on site and usually after the installation of the drainage/protective layers. Basically, they are based on general similarities between water flow and electric current flow. The contaminant flow is substituted by electric current flow through the damage in the geomembrane. Sensors installed beneath or above the geomembrane measure the current flow. Due to the high sensitivity of the method, damage detection is rapid and the precise location of the damage enables repairs to be effected. Depending on the type of the project, e.g. landfills, tanks, basins, dams, storage and similar facilities, and the client's need, there are several modifications available. Due to the growth of applications of the electrical monitoring systems in the world we have tried to specify and describe where the limits are of the use of such monitoring. We describe the "boundary conditions" and their appearance in practice. The results are in graphs. Another aim is the description of the "shield effect" we discovered during our field work. In addition, the dependence of electrical anomaly on the size of the hole and its position are discussed and modeled.

Keywords: Geomembranes, Installation damage, Leak detection, Monitoring, Testing.

1 INTRODUCTION

The electric leak detection and location systems are now available in several countries. As the advantages of the system are significant, its use continues to grow together with the geomembrane market. Seeing this expansion we have described the advantages and limitations of such systems and advise people who are responsible for their application (local authorities, designers, etc.).

The basic principle of the electric monitoring systems is the creation of an electric field on one side of a geomembrane and reception of an electric potential difference between two sensors on another side of a geomembrane. If any changes of integrity of the geomembrane appear, an electric potential difference increases or decreases and creates an anomaly in the electric field. The fixed installed sensors or mobile probes register this anomaly by special electronic equipment. It is stored either in a portable computer in the case of off-line monitoring, or into a desktop computer in the case of on-line monitoring (only in case of fixed systems). After several steps of processing and analysis, the data are interpreted and displayed on the screen of a computer. The position of the place where a change of integrity of the geomembrane occurs is precisely computed and shown. Thus a failure is revealed with high precision thus avoiding cost of extensive digging.

Another parameter by which we can divide systems into main groups is that of measured electrical parameters. As described, results are obtained by the method of using measurement of potential difference between two sensors. Other systems used, include measurement of the variation of electrical current, variation of capacitance, measurement of changes of resistivity/conductivity of the subgrade under the geomembrane due to flows of contaminated water liquid through holes.

The electric systems can be divided into two basic groups, fixed systems and mobile systems (see Table 1). The fixed systems named leak/damage detection systems used worldwide can be divided into three groups with different positions of the sensors in relation to the geomembrane (Nosko 1999):

- sensors are located under a geomembrane
- sensors are located above a geomembrane
- sensors are located above and beneath a geomembrane.

Table 1: Systems for the testing and the monitoring of the integrity of the geomembranes – Classification by Nosko 1999.

<table>
<tr><td colspan="10">Classification of the monitoring systems</td></tr>
<tr><td colspan="8">Direct Detection of the Integrity of the geomembranes</td><td colspan="2">Non-direct Detection of the Integrity of the geomembranes</td></tr>
<tr><td colspan="5">Electric systems</td><td colspan="2">Penetration of indicative chemicals</td><td>Others</td><td>Monitoring wells, pipes ...</td><td>Under liner drainage</td></tr>
<tr><td colspan="3">Fixed position of the sensors (possibility of short and long time monitoring)</td><td colspan="2">Mobile systems</td><td>Liquid</td><td>Gas</td><td>Optofibers, etc.</td><td></td><td></td></tr>
<tr><td>Under the geomembrane</td><td>Under and above the geomembrane</td><td>Above the geomembrane</td><td>Mobile probes</td><td>Water puddle</td><td></td><td></td><td>Geophysical surveys</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td>Water lance</td><td></td><td></td><td>Conductive geomembrane</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>Conductive and non-conductive geotextile</td><td></td><td></td></tr>
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2 BOUNDARY CONDITIONS IN PRACTICE

An electrical leak/damage detection and location systems looks very simple at first sight, of the simplified theory, the measured parameters, configurations on site, sometimes simple measuring devices, etc. Nothing is as simple as that. The work becomes more difficult when we want to correct measurement and processing with analysis. Many questions arise In this paper we would like to highlight two basic facts we discovered during our active field works done worldwide in 16 countries. These are:

- Shield effect
- Size of hole vs. position of hole regarding the sensor.

2.1 *Shield effect*

Shield effect is one of the most important and the most difficult fact regularly appearing during application of electrical monitoring systems. The basic explanation is needed of the fact that a hole in the geomembrane can hide another one by his amplitude of anomaly. This hole by its contribution to the deformation of general electric field can change dramatically the distribution of the surrounding electric field. The most important parameter in this situation is the position of hole. We study this phenomenon experimentally in the field condition by influence of 3 holes of the same diameter (see Figure 1-2). It can be seen that in the case of hole situated directly in place of sensor or very near it creates an electrical anomaly which can completely hide all other existed anomalies created by holes nearby. The area covered by influence of this hole depends on the conductivity of the layer where sensors are located. Therefore we recommend after one hole has been repaired, a new test is done in the area around this hole and not just in the local area. The re-tested area must by a minimum of 3 to 5 x the distance between grid lines (profile lines).

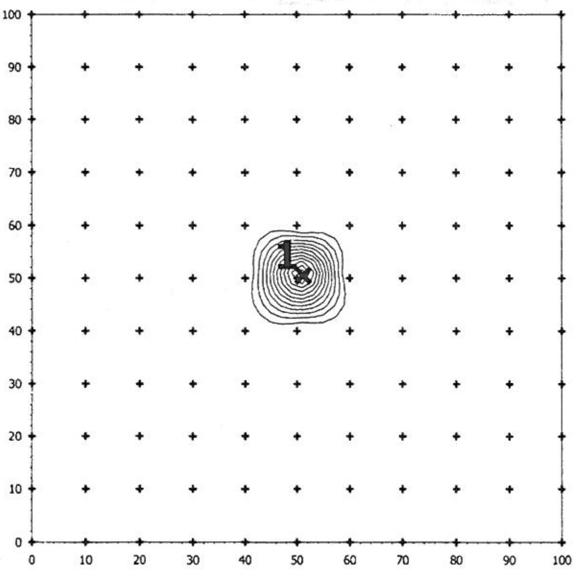

Figure 1. Detected anomaly near the sensor.

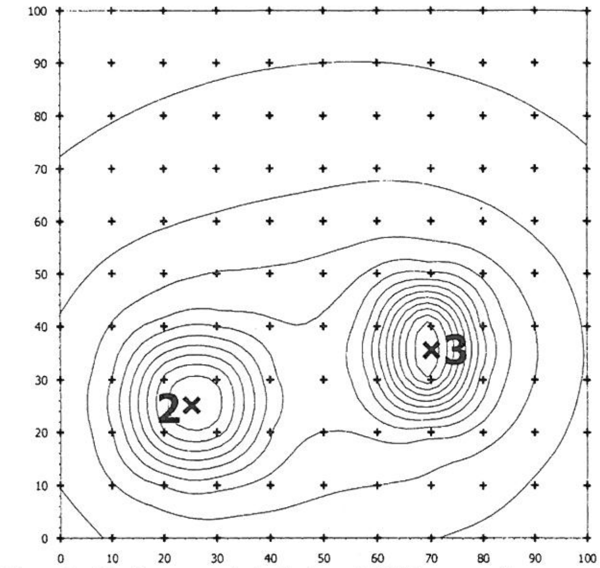

Figure 2. The first anomaly is eliminated. Hidden anomalies appear.

2.2 *Size of hole vs. position of hole to the nearest sensor*

The phenomena of size of hole and position of hole are the very important one in case of study of amplitude of anomaly vs. size of hole creating this anomaly. Many clients ask if we are able to say something about size of hole when we present electrical anomalies for them. Basically, a small hole very near a sensor creates a huge anomaly compared with a large hole far from the same sensor (e.g. situated between four sensors).

The influence of a failure within a weld was simulated by input of HDC (conductive PEHD). Part of weld was done by lower temperature to maintain conductivity of material. It can be seen that influence of such failure was not great compared with even small holes in the geomembrane (Figure 3).

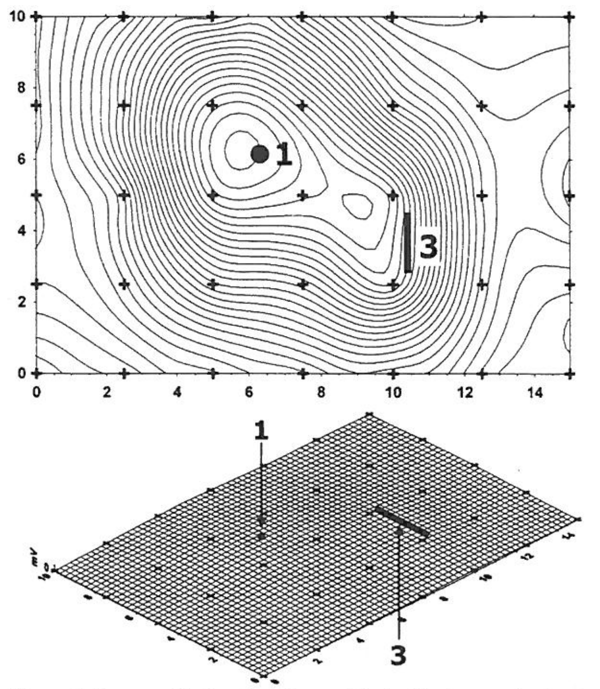

Figure 3. Damage No.1 – 2 mm^2 round hole; No.3 – conductive hot wedge weld.
Step of isolines = 0.5 mV; Z (max) = 6.5 mV; scale 1:1:25.

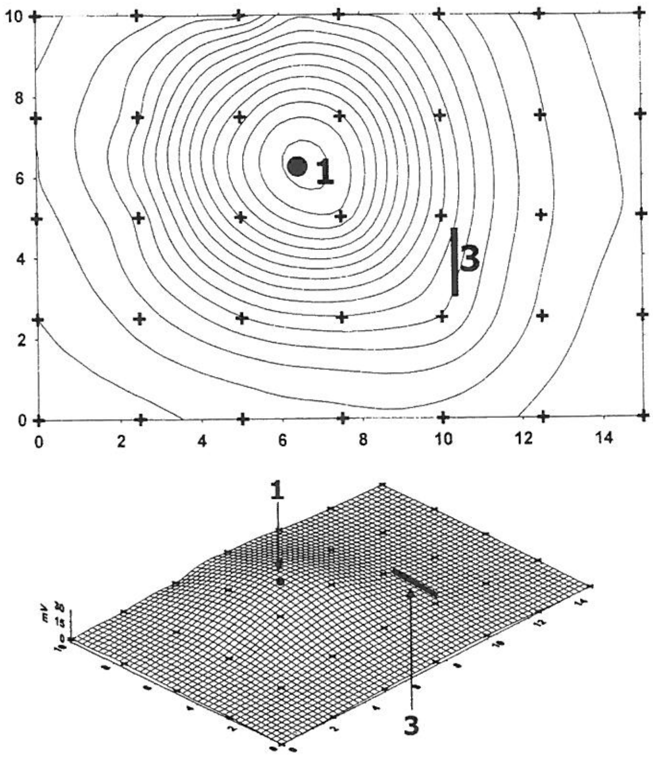

Figure 4. Damage No.1 – 12.5 mm^2 round hole ; No.3 – conductive hot wedge weld.
Step of isolines = 2 mV; Z(max) = 32 mV; scale 1:1:25

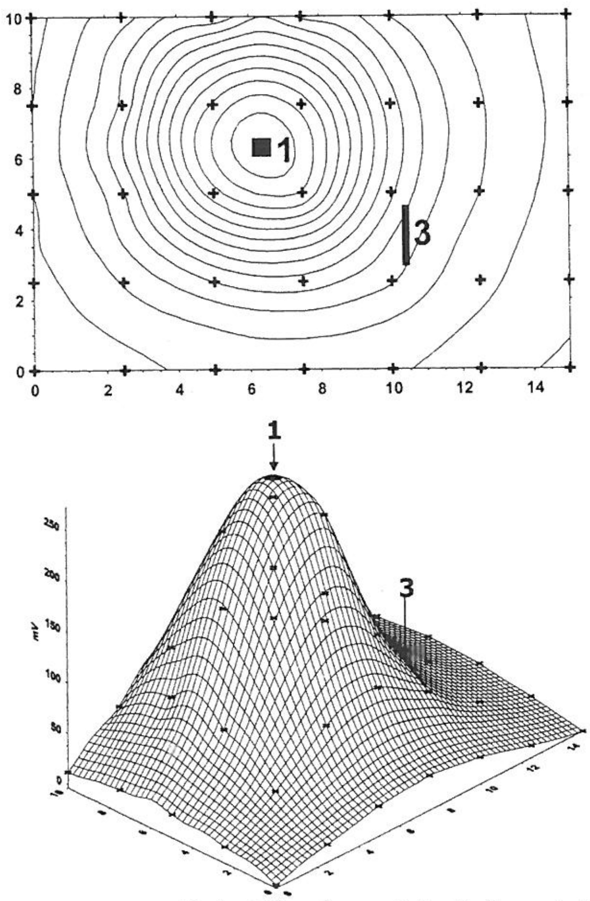

Figure 5. Damage No.1 – 100 mm^2 square hole ; No.3 – conductive hot wedge weld.
Step of isolines = 20 mV; Z(max) = 273 mV; scale 1:1:25

Due to bigger size of hole No.1 in case of Figure 3 the anomaly of the conductive hot wedge weld almost disappeared (Figure 4). The size of hole No.1 (12.5 mm^2) allows better conductive contact through the geomembrane.

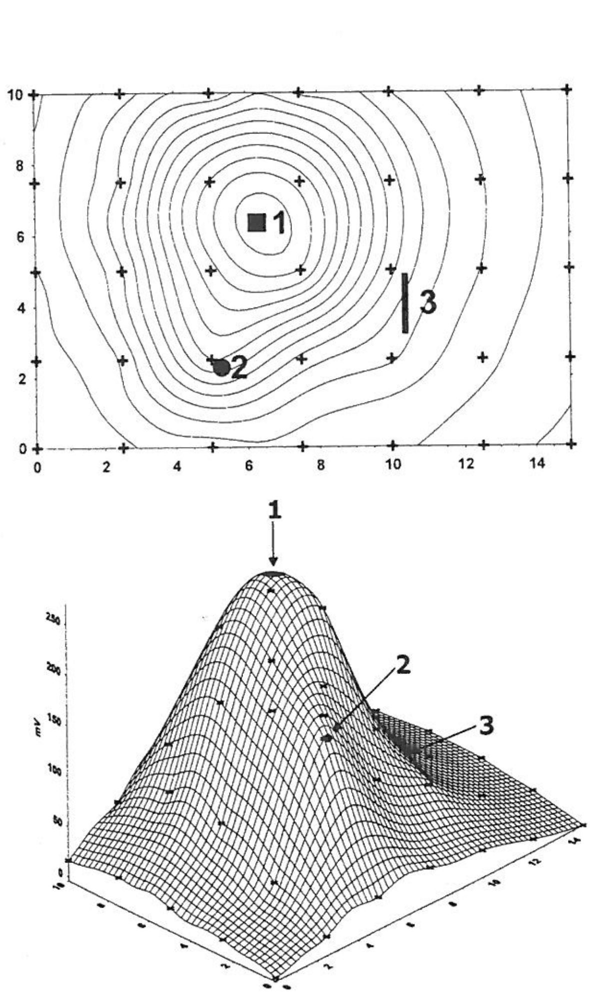

Figure 6. Damage No.1 – 100 mm^2 square hole; No.2 – 3 mm2 round hole;
No.3 – conductive hot wedge weld.
Step of isolines = 20 mV; Z(max) = 270 mV; scale 1:1:25.

3 CONCLUSION

It can be seen from the experimental results presented in this paper that the existence of shield effect can cause problems if ignored. Sometimes we are victims of rapid re-check of damaged area after repairs. Often only very close area is controlled again. It is necessary to control a wider area than the immediate vicinity of the repaired holes. Of course, the area to be rechecked depends on several other parameters e.g. sensitivity of detection, conductivity of layer where sensors or mobile probes are placed, etc.

The possibility of the evaluation of a size of a hole detected by electrical systems based on shape and amplitude of electrical anomalies appears very difficult. The strong dependence of the electrical anomaly on the position of a hole eliminates the influence of the size of hole. The real data obtained under field conditions show how important are the locations of holes.

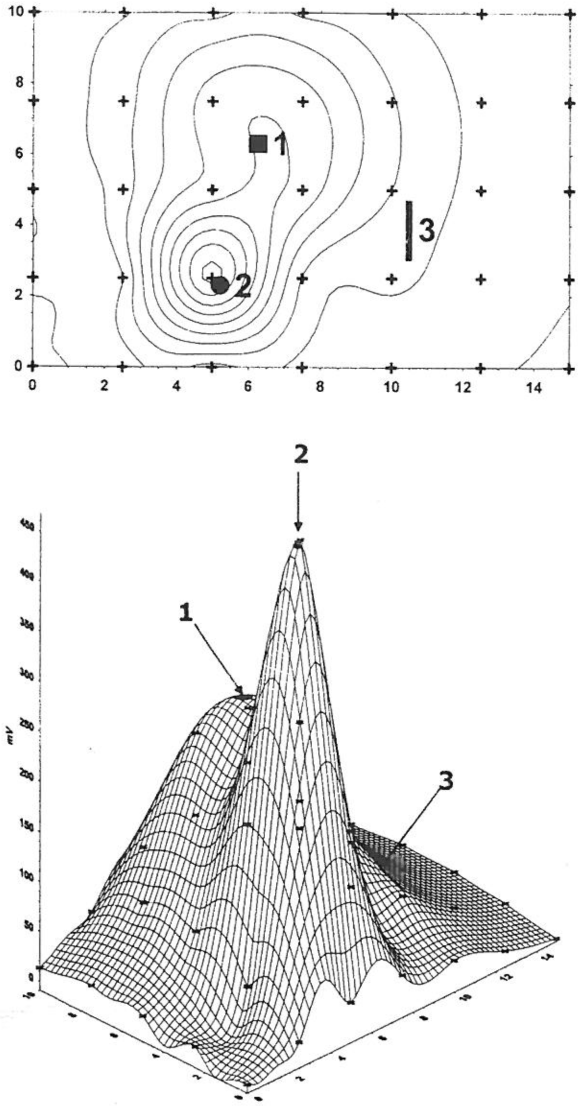

Figure 7. Damage No.1 – 100 mm^2 square hole; No.2 – 12.5 mm2 round hole;
No.3 – conductive hot wedge weld.
Step of isolines = 50 mV; Z(max) = 486 mV; scale 1:1:25.

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