IMPACTS AND LIMITATIONS OF QUALITY ASSURANCE ON GEOMEMBRANE INTEGRITY

Statistical Study Based on a Decade of Leak Location Surveys

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ABSTRACT

This paper has for goal the measurement of the impacts and the limitations of Quality Assurance applied to containment sites lined with geomembrane. Statistics obtained from leak detection surveys performed on exposed geomembranes (totalling 2 291 000 m²), as well as on covered geomembranes (totalling 361 000 m²) over a ten year period have been analyzed to complement recently published data, and to stress the necessity of implementing rigorous Construction Quality Assurance (CQA) programs during geomembrane installation. We herein present statistics showing a global decrease in the number of leaks found on sites where a rigorous CQA program was performed.

It was found that the relation between geomembrane leak density and the application or not of a rigorous CQA program during installation and covering is crucial. The CQA allows a preventive control of leaks and considerably reduces their number. In conclusion, this paper proposes that Quality Assurance when combined with leak detection ensures the integrity of a confinement works.

1. INTRODUCTION

Leak detection surveys performed on exposed geomembranes (totalling 2 291 000 m²), and covered geomembranes (totalling 361 000 m²) during a ten year period, totalling 89 projects located in 8 different countries, have been analyzed in order to complement recently published data, and to stress the importance of implementing rigorous Construction Quality Assurance (CQA) programs during geomembrane installation. The data collected was used to calculate the number of leaks per hectare (leak density) for each project, and to register the types and sizes of the located leaks. Statistics presented in this paper are extracted from a previous publication: Lessons Learned from 10 years of Leak Detection Surveys on Geomembranes (Forget B. 2005a, Forget B. et al. 2005b).
Short descriptions of the two different leak detection techniques used to verify the integrity of geomembranes are presented: a) the water puddle technique as used on exposed geomembranes either during or after installation, b) the dipole technique as applied to geomembranes covered with a soil layer.

Statistics indicating a global decrease in the number of leaks found on sites where a rigorous Construction Quality Assurance program was implemented are presented in support of the Giroud statement published more than 20 years ago at the first International Conference on Geomembranes held in Denver, Colorado: «The main reason, I believe, is that many people, when they use geomembranes, tend to neglect two important aspects, design and quality assurance… » (Giroud, 1984).

Finally, we propose that Quality Assurance is indissociable from geoelectric leak detection, the latter as a geomembrane integrity measuring tool, the former through its preventive role. When combined and used jointly, Quality Assurance and leak detection presently offer the best assurance concerning the waterproofness of a containment works.

2. GEOELECTRIC LEAK DETECTION TECHNIQUES

Geoelectric leak detection techniques used on geomembranes have been described in many publications, such as Peggs (1989, 1990, 1993), Darilek et al. (1988, 1989), Laine et al. (1989, 1991, 1993) and Rollin et al. (1999, 2002, 2004). Three standard guides, ASTM D6747 (Standard Guide for Selection of Techniques for Electrical Detection of Potential Leak Paths in Geomembranes), ASTM D7002 (Standard Practice for Leak Location on Exposed Geomembrane Using the Water Puddle System) and ASTM D7007 (Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials), have been developed recently to support the implementation of these techniques. These can be applied to most of the polymeric geomembranes (PE, PVC, fPP, modified bituminous) with the exception of EPDM that is considered electrically conductive.

The water puddle method (ASTM D7002) consists in the creation of a potential difference between the soil under an exposed geomembrane and a puddle of water projected from a diffuser onto the surface. Most geomembranes are highly resistant electrical insulators and inhibit electrical currents. As soon as water percolates through a perforation and reaches the supporting soil, a ‘bridge’ is created between these two potentials, which generates an electrical current. A detector signals the presence of an infiltration to the operator (via acoustical and visual signals). This technique permits the detection of leaks with dimensions of 1 mm² or greater.

On-site preparation is minimal, and generally, the survey can be carried out during the geomembrane installation. The prospecting rate is approximately 5000 m²/day/operator, depending on site conditions. To achieve this survey rate, a continuous water supply of approximately 4 m³/day/operator is necessary. This water supply may be provided from a tanker or a direct connection to a municipal network. If a water supply
proves difficult to find, the use of a closed circuit with a low point is also possible. Figure 1 provides a general diagram of the water puddle method.

*Figure 1: Water Puddle Technique on Exposed Geomembranes*

In the dipole leak detection technique *(ASTM D7007)*, an electrical potential is applied between the covering material above the geomembrane and the soil below it. Since most synthetic geomembranes are effective electrical insulators, the presence of a leak creates a localized passage of current, which perturbs the potential field in a characteristic way. Leaks are located by recording potential readings with the dipole at predetermined grid densities.

Under moderate climatic conditions, on-site preparation is minimal. Under very dry conditions, spraying water on the covering soil surface might be necessary in order to insure good contact with the dipole. The detection limit is variable but generally allows detection of holes with dimensions of 6 mm² or greater. Figure 2 provides a general diagram of the dipole method.

*Figure 2: Dipole Technique on Covered Geomembranes*
3. IMPACT AND LIMITATIONS OF CQA ON GEOMEMBRANE

Although Quality Assurance during geomembrane installation is compulsory in many confinement works, the methods used for this test vary according to the country, the type of works, the state of environmental concerns, policy makers, the client as well as the firm carrying out the test. With the use of a geomembrane, clients tend to have an exaggerated confidence in the product, and this at times to the detriment of proper installation. The installation stages, and Quality Assurance carried out by the installer under the supervision of a third party have a determining effect on geomembrane integrity.

Many questions about geoelectric leak detection have been raised among clients sponsoring confinement works, while the value of conventional Quality Assurance programs as used for the past many years, has been called into doubt. The efficiency of applying a Quality Assurance program combined with geoelectric leak detection will be demonstrated in the following sections. The indissociable character of Quality Assurance and geoelectric leak detection in insuring the integrity of confinement works is highlighted.

The results and conclusions drawn in this article have been obtained from more than 2 000 000 m² of prospected surfaces using one of the two techniques described above, and result from ten years of prospecting. We first demonstrate the importance of Quality Assurance (QA), by the fact that it helps prevent the formation of leaks; we subsequently show that geoelectric leak detection, when used as a measuring tool, allows a final test to determine geomembrane integrity.

In terms of this article and of the statistics compiled, a CQA program is defined as a constant surveillance by an expert with recognized expertise in geomembrane installation, during all of the liner installation stages, including subgrade preparation, liner installation, seaming procedures, and covering of the geomembrane.

The data obtained for different HDPe geomembrane thicknesses was gathered to determine the influence on the quantity of perforations during covering. The results obtained for covered geomembranes for a total surveyed area of less than 10 000 m², and projects where QA did not conform to the criteria outlined above, were discarded in order to permit an objective comparison of the influence of CQA programs and leak detection surveys.
### Table 1: Leak Density Comparison (HDPE Geomembranes)

<table>
<thead>
<tr>
<th>Geomembrane Thickness</th>
<th>Exposed HDPE Geomembranes (Water Puddle)</th>
<th>Covered HDPE Geomembranes (Dipole)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Column 1</td>
<td>Column 2</td>
</tr>
<tr>
<td>With CQA</td>
<td>With CQA and geoelectrical leak survey (water puddle) before covering</td>
<td>Without CQA nor geoelectrical leak survey (water puddle) before covering</td>
</tr>
<tr>
<td>Without CQA</td>
<td>Without CQA</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Number of leaks per hectare (prospected area m²) – quantity of site prospected</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0 mm</td>
</tr>
<tr>
<td>3.2 (362 460) – 32</td>
</tr>
<tr>
<td>1.5 mm</td>
</tr>
<tr>
<td>5.1 (66 880) - 4</td>
</tr>
<tr>
<td>1.0 mm</td>
</tr>
<tr>
<td>20.5 (17 070) - 2</td>
</tr>
</tbody>
</table>

An analysis the statistics in table 1 helps us to clearly visualise the incidence of QA on the number of leaks per hectare. For the exposed geomembrane, the numbers in columns 1 and 2 with a membrane of 1.0 mm show a 35% reduction in the number of leaks. Columns 3 and 4 allow us to measure the incidence of combining both QA and leak detection using the water puddle technique before covering (Column 3), when compared to a covered geomembrane installed without QA or leak detection (Column 4). In this instance, QA combined with water puddle leak detection reduced the number of leaks later detected using the dipole technique on the covering surface by 78 times (15.6 vs. 0.2).

The value of QA lies principally in the fact that it helps prevent punctures by having a visual evaluation on the foundation surface carried out before installation of the geosynthetic material.

With the great efficiency of leak detection techniques, some may wonder if applying these geoelectric leak detection techniques could be a substitute for QA programs. Is it really necessary to have a team of observers during geomembrane installation if the leaks are subsequently found during the implementation of a leak detection program?

Implementing a CQA program is a must. Photo 1 clearly demonstrates the incidence of the absence of a CQA program on the long term performance of the works. Dipole detection on covered geomembrane with a drainage of 0.5 m uncovered 16 punctures on a 5 000 m² surface. These works had to support a charge of more than 250 kPa at the geomembrane level. We can observe several potential punctures on the uncovered geomembrane (around 40), caused by the non conformity of the foundation surface. The majority of these potential punctures would have in effect perforated the geomembrane under the pressure of the waste material. These works were completely done over once these observations were made.
This example clearly demonstrates that dipole leak detection only allows to find existing leaks, not those weak areas that are future potential leaks. Leak detection can never be a substitute for Quality Assurance. A strict testing of the foundation must be performed by a third party, a recognized expert, in order to insure the integrity of the geomembrane, considering the progressive increase in pressure exercised on it, once it is put into use.

Even though it has been demonstrated that the preventive aspect of QA reduces substantially and without a doubt the number of leaks, it remains that QA alone cannot insure the integrity of the works, as the numbers in Table 1 show.

On the other hand, analysis of the data of Table 1 shows a low leak density on covered HDPe geomembranes (Column 3), when a joint QA and water puddle leak detection program was performed prior to covering the geomembrane. Some may be tempted to skip the dipole detection, considering the low probability of finding any leak. But one has to consider the dimensions of the perforation, as well as the number of leaks.
Table 2: Leak Size as a Function of Leak Type (Colucci et al (1995))

<table>
<thead>
<tr>
<th>leak size (mm²)</th>
<th>holes</th>
<th>tears</th>
<th>cuts</th>
<th>seams</th>
<th>total</th>
<th>% total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-20</td>
<td>44</td>
<td>31</td>
<td>12</td>
<td>11</td>
<td>98</td>
<td>23</td>
</tr>
<tr>
<td>20-100</td>
<td>37</td>
<td>49</td>
<td>21</td>
<td>4</td>
<td>111</td>
<td>26</td>
</tr>
<tr>
<td>100-500</td>
<td>60</td>
<td>49</td>
<td>2</td>
<td>8</td>
<td>119</td>
<td>28</td>
</tr>
<tr>
<td>500-1000</td>
<td>22</td>
<td>11</td>
<td>0</td>
<td>4</td>
<td>37</td>
<td>9</td>
</tr>
<tr>
<td>1000-10000</td>
<td>10</td>
<td>22</td>
<td>0</td>
<td>1</td>
<td>33</td>
<td>8</td>
</tr>
<tr>
<td>&gt; 100000</td>
<td>15</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>188</td>
<td>171</td>
<td>35</td>
<td>28</td>
<td>422</td>
<td></td>
</tr>
</tbody>
</table>

Data reported by Colucci et al (1995) is presented in Table 2. Approximately 80% of all detected leaks are smaller than 500 mm² with larger leaks being holes and tears. For covered and uncovered geomembranes, Nosko et al (2000) found that the predominant size of stone-related damage is typically 50 to 200 mm²; damage related to heavy equipment is typically larger than 1000 mm²; damage related to faulty welds is typically under 50 mm²; damage related to cuts is typically 50 to 200 mm² (see Table 2). This information can be compared with leaks found by Colucci et al (1995), Phaneuf et al (2001) and Rollin et al (1999).

Analysis of data relating to the dimensions and types of leaks shows that the majority of perforations detected by the dipole technique where QA and water puddle detection were previously performed, were caused by the equipment used during covering (mechanical shovel and bulldozer) and that the tears ranged from a few centimetres to close to a meter in length.

Photo 2 illustrates a tear in the geomembrane caused by covering equipment. Despite the full-time presence of someone in charge of QA on the worksite, a 1 metre long tear was caused inadvertently by an equipment operator. Without dipole leak detection technique, this leachate pond could not have been made operational.

Photo 2: A one metre tear, discovered using the dipole method, caused by heavy equipment during covering of the geomembrane.
4. CONCLUSION

The relation between leak density and the presence or absence of a rigorous CQA program has been demonstrated to be crucial. It was found that most perforations happen during geomembrane installation and not during its covering phase whenever a rigorous CQA program is implemented. However, larger tears and holes are usually encountered during the geomembrane covering stage.

The results and conclusions drawn in this article have been obtained from more than 2 000 000 m$^2$ of prospected surfaces using the two techniques described above, and correspond to ten years of prospecting. We have demonstrated the importance of Quality Assurance (QA), by the fact that it helps prevent the formation of leaks; we have further shown that geoelectric leak detection, when used as a measuring tool, allows a final test to determine the integrity of a containment site.

Long term performance of a containment site is measured by the total efforts deployed at the laying of the foundation, welding of the panel joints, and covering stages, as well as during leak detection and operation of the works.

On a short term basis, leak detection allows us to qualify the geomembrane and to ensure its integrity at the time it is put into operation. QA and rigorous testing of the foundation, performed by an expert third party, ensure the long term integrity of the geomembrane, considering the progressive increase of pressure it will eventually be submitted to. QA and geoelectric leak detection, when used jointly, are today the best guarantee of short and long term integrity of a containment works using geomembranes.

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