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Evaluation of the real performance of an electrical geomembranes leak detection system: Full scale experimental study

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ABSTRACT: Leak location testing using electrical methods is currently being used in liner construction quality assurance (CQA) to locate leaks in geomembranes. Several papers have reported results on installed geomembranes in terms of density, i.e. number of leaks/hectare found, but do not give detailed information on the true efficiency of the methods in terms of percentage of holes or defects found, compared with the actual existing number of defects. The Laboratoire Régional des Ponts et Chaussées de Nancy (French Roads Administration) has performed experimental "full-scale" tests in order to determine the true "performance level" of a water lance (water spray probe) detection system to scan exposed geomembranes. The paper presents the results obtained in terms of effectiveness (number of leaks found/number of leaks really existing), accuracy (size of the smallest detectable defects), parameters of influence, validity and limits of the method.

1 INTRODUCTION

The use of geomembranes lining systems in civil engineering and environment protection works is more and more frequent in France as indeed it is throughout the world. If installation techniques and construction quality assurance (CQA) plans have been improved with the years, the defects, mainly due to installation operations, still remain that may cause leakage. Since the French legislation on CQA takes a new guidance and requires specifications in terms of performance, the detection of these defects, in order to repair them, is an essential part of on site controls to ensure the efficiency during the service life of geomembranes lining systems. Leak detection methods have been developed that allow the inspection of the overall surface of geomembranes as opposed to only the seams as is the case with classical non-destructive control methods of seamwelds. The Laboratoire des Ponts et Chaussées de Nancy has tested an electrical leak detection system for uncovered geomembranes, developed by an international company for its own requirements. This paper presents the first experiments carried out in order to verify the characteristics and limits of validity or performance of that system.

2 EXPERIMENTAL PROGRAM

2.1 *Apparatus*

The apparatus tested is a mobile model using the "puddle water method". The water puddle method consists in the creation of a potential difference between a soil under an exposed geomembrane and a puddle of water projected from a diffuser onto the surface. The water puddle is pushed systematically over the geomembrane area to locate the points where the electrical current flow increases. 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). The water puddle detection system usually consists of a horizontal water spray manifold (diffuser) with multiple nozzles that spray water onto the exposed geomembrane, a squeegee device to push the resultant puddle of water, and a handle assembly. A pressurized water source is connected to the spraying manifold using a plastic or rubber hose (Behaxateguy 1999, Rollin 1999, Peggs 2001).

2.2 *General experimental plan*

Three types of geomembranes commonly used, PVC, HDPe, bitumen, are tested. The prospected surfaces are the following:

– PVC: 80 m^2, 2 widths (20 m × 2 m) seamed by an automatic double weld with central canal.
– HDPe: 50 m^2, 2 widths (10 m × 2.5 m) seamed by an automatic double weld with central canal.
– Bitumen: 80 m^2, 2 widths (20 m × 2 m) manual seamed

In order to minimize the influencing parameters and to obtain the best results, geomembranes are installed on a perfectly flat surface covered by a 300 g/m^2 needle-punched geotextile, and the soil and the geotextile are previously humidified to assure a perfect contact between soil and lining system.

Two operators participated to the test. One (operator A) is well experienced, the other one (B) is less experienced. They carried out the test independently. Each person scanned a half-width of each type of geomembrane. They completely ignored the number, situation, type and sizes of defects.

The defects are made by a "third party" operator and located accurately on a plan. Different types of defects are made:

– "cut-out holes" (with loss of material): made with dies of different diameters (2-10 mm)
– perforations (without loss of material): made with a punch or cross-shaped screwdriver (Φ < 1 cm)
– cuts: made with a knife (2 to 25 cm)
– notches: made with a small cutter (< 2 mm)
– punctures: made with a needle (0.5 mm)

All the defects may result in a leak since they go through the entire thickness of the geomembrane. The density is between 0.25 to 2 defects/m^2, much higher than the density of defects detected in real works as landfills (3 to 25/ha) (Rollin 1999, Behaxateguy 1999). The cuts are made in different directions: parallel, perpendicular or at a 45° angle from the direction of the survey. The ambient temperature during the tests was nearly 30°C.

3 RESULTS

3.1 *PVC geomembrane*

Table 1 gives, for each operator, the number of defects found compared to the actual number of defects made by the third operator and the global result, also expressed in percentage.

Details (Remarks)

– 1 hole (Φ = 3 mm) not found: located on the same line as a 4 mm hole at a distance of only 10 cm
– 3 cuts not found: all of them parallel to the survey direction, 2 "hidden" under the free edge of the seam
– 97% of holes (> 3 mm) found, 2 of them on the same line perpendicular to the surveying direction and only 25 cm from each other
– 5 of 8 defects located on the seam are found, 2 of them "hidden" under the free edge of the seam, 3 on the welded track.

Table 1. Detection rate on PVC geomembrane.

Defects Type (size)	**Operator A** Nbr of defects Found/actual	**Operator B** Nbr of defects Found/actual	**Global** Nbr of defects Found/actual
Hole (3 mm)	10/10 (100%)	7/8 (87%)	17/18 (95%)
Hole (4 mm)	–	6/6 (100%)	6/6 (100%)
Hole (6 mm)	4/4 (100%)	6/6 (100%)	10/10 (100%)
Knife cuts	8/9 (89%)	8/10 (80%)	16/19 (85%)
Perforations	0/5 (0%)	0/4 (0%)	0/9 (0%)
Notches	–	0/2 (0%)	0/2 (0%)
Total	22/28 (78%)	27/36 (75%)	49/64 (76%)

Comments

The ratio of detected defects (78% and 75%) is independent of the operator. None of the smallest "closed" defects (perforations, notches) is found. When two defects are very close, one may occult or "mask" the other one, especially if they are on a same line perpendicular to the prospecting direction.

3.2 *HDPe geomembrane*

Table 2 gives, for each operator, the number of defects found compared to the actual number of defects and the global result, also expressed in percentage.

Table 2. Detection rate on HDPe geomembrane.

Defects Type (size)	**Operator A** Nbr of defects Found/actual	**Operator B** Nbr of defects Found/actual	**Global** Nbr of defects Found/actual
Hole (2 mm)	1/1 (100%)	–	1/1 (100%)
Hole (3 mm)	5/5 (100%)	4/5 (80%)	9/10 (90%)
Hole (4 mm)	2/2 (100%)	3/3 (100%)	5/5 (100%)
Knife cuts	5/8 (62%)	4/5 (80%)	9/13 (69%)
Perforations	3/4 (75%)	6/7 (86%)	9/11 (82%)
Notches	0/3 (0%)	0/3 (0%)	0/6 (0%)
Punctures	1/4 (25%)	1/3 (33%)	2/7 (28%)
TOTAL	17/27 (63%)	18/25 (71%)	35/53 (66%)

Details (remarks)

– 4 knife cuts (2 to 10 cm) not found, 3 being parallel to the surveying direction
– 95% of holes detected
– 100% of the defects located on the seam, under the free edge, on the central canal or on the welded tracks, are found

Comments
As in the case of PVC the results are similar for operator A and B. The rate of detection of the smallest defects, notches and punctures, is very low even if 2 punctures are found. The rigidity of HDPe can explain the high detection rate (82%) compared with the 0% obtained on PVC for the same type of defects: (1) the perforations remain partly open and the leakage can easily occur, (2) the perforations have left "prints" on the geomembrane; these prints are easily visible to the eye on the clean surface, so the operator can "anticipate" the defect and pay it more attention as well as take more time for detection until he gets a signal.

3.3 *Bituminous (elastomeric) geomembrane*

Table 3 gives, for each operator, the number of defects found vs. the actual number of defects and the global result, also expressed in percentage.

Table 3. Detection rate on bituminous geomembrane.

Defects Type (size)	**Operator A** Nbr of defects Found/actual	**Operator B** Nbr of defects Found/actual	**Global** Nbr of defects Found/actual
Hole (3 mm)	3/12 (25%)	2/10 (20%)	5/22 (23%)
Hole (6 mm)	5/6 (83%)	9/10 (90%)	14/16 (87%)
Hole (8 mm)	6/7 (83%)	3/4(75%)	9/11 (82%)
Hole (10 mm)	–	2/2 (100%)	2/2 (100%)
knife cuts	4/6 (67%)	1/6 (17%)	5/12 (0%)
TOTAL	18/31 (58%)	17/32 (53%)	35/63 (55%)

Details (remarks)
- 5 "parasite" signals were registered but none was linked to a real defect
- 3 holes "suspected" but not exactly localized
- 2 holes (3 mm) not found, located very close to other defects found (< 25 cm) situated on the same cross-survey direction line
- none of the cuts (4 to 18 cm) parallel to the surveying direction are found; all the "perpendicular" cuts (3 to 23 cm) are detected.

Comments
The detection rate is the same for both operators. This rate is relatively low, very low for holes of 3 mm in diameter, medium for cuts. Two assumptions can applied to this fact:

(1) the "self-healing" ability of bitumen that smelted under the high external temperature (it is the reason why no perforations have been done in bituminous geomembrane),
(2) the thickness of the geomembrane, that needs a more important water puddle above the geomembrane: the operators established that the water consumption is much higher than for PVC and HDPe.

It is supposed that metallic particles resulting from the production process are at the origin of the 5 parasite signals registered

3.4 *Synthesis of results*

Since the results seem independent of the operator, it is possible to try an other analysis ant to give global results as functions of the type and/or size of defects obtained for each type of geomembrane.

Notations: in the following table knife cuts are separated as "SD" and "CSD": "SD" cuts are parallel to the survey or scanning direction (i.e. perpendicular to the squeegee), "CSD" cuts (cross survey direction) are perpendicular to that direction. N & P = notches and punctures

Table 4 gives global results as functions of the type and/or size of defects and type of geomembrane.

Table 4. Global results.

Defects Type (size)	**PVC** Nbr of defects Found/actual	**HDPE** Nbr of defects Found/actual	**Bitumen** Nbr of defects Found/actual
Hole (2 mm)	–	1/1 (100%)	–
Hole (3 mm)	17/18 (95%)	9/10 (90%)	5/22 (23%)
Hole (4 mm)	6/6 (100%)	5/5 (100%)	–
Hole (6 mm)	10/10 (100%)	–	14/16 (87%)
Hole (8 mm)	–	–	9/11 (82%)
Hole (10 mm)	–	–	2/2 (100%)
"SD cuts"	9/12 (75%)	7/10 (70%)	0/7 (0%)
"CSD cuts"	7/7 (100%)	2/3 (66%)	5/5 (100%)
Perforations	0/9 (0%)	9/11 (82%)	–
N & P	0/2 (0%)	2/13 (15%)	–
TOTAL	49/64 (76%)	35/53 (66%)	35/63 (55%)

Comments
Concerning PVC and HDPe the detection rate is over 90% for holes smaller than 3 mm, 100% for holes bigger than 3 mm while these rates are respectively only 23% and 85% for bitumen.

About knife cuts, it may be seen that almost 100% of those with a 45° angle/surveying direction or perpendicular to the surveying direction are detected, as opposed to only 70% to 75% of the cuts parallel to the surveying direction, with the exception of bitumen (0%); the difference may be explained by the fact that the pressure exerted by the squeegee or water pipe distributor maintains the "lips" or edges of the "SD" cuts in a closed position, and tend to separate or open them in the case of "CSD" cuts.

No perforation is found on PVC while 82% are found on HDPe. The two types of geomembranes have different behaviour: the HDPe is rigid and tends to maintain the deformations and the perforations stay partly open while they remain closed in the case of a flexible PVC.

Could the reason why the smallest defects are not detected (< 15%) be: insufficient "water quantity" on the geomembrane?

4 CONCLUSION

The experimental program has demonstrated that he method is reproducible, independent of the operator provided he has a minimum of knowledge and practice with the equipement.

The reliability is good, especially for polymeric geomembranes, with a detection rate between 65% and 75%. The accuracy allows the detection of holes approximatly 2 mm and smaller, but is variable following the "mechanical" behaviour (rigidity, suppleness) of the membrane tested. A relative "blindness" is shown by the instrument when 2 or many defects are very close together mainly if they are located on a same line perpendicular to the surveying direction, but this may also be explained somewhat by the operator's experience or lack thereof.

Finally these first results lead us to ask some questions or express hypotheses that are to be answered or verified by further experiment. A particular attention must be given to the incidence of external temperature in case of bituminous geomembrane surveys. The actual accuracy, i.e. the size of the smallest defect that can be found should be thoroughly studied for all types of geomembranes, especially by taking into account the thickness of the product.

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