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LFE8 - Geophysical testing of geomembranes used in landfills

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Contents

1.0 Introduction

Geomembranes are frequently used as an element in the lining systems for landfill sites. Installing them requires particular care to ensure the liner provides a continuous seal across the entire site. Geophysical testing provides an effective means of confirming a geomembrane is forming a complete seal beneath a body of waste. Essentially, there are two main geophysical test systems currently in use, mobile surveying and fixed test systems. Where a risk assessment indicates they are appropriate, we prefer fixed systems as they can provide information over a number of years, rather than the snapshot a mobile survey provides.

This document explains the theory behind the different types of geophysical surveys. We hope it will provide landfill operators with the knowledge they need to appreciate the technology and terminology used. You can find guidance on other aspects of geomembranes in Using geomembranes in landfill engineering (Environment Agency 2008)

Geophysical testing differs from leak collection systems in that the latter provide a physical collection system. Leak collection systems are placed under a landfill liner into which fugitive leaks are collected and channelled to a collection point. This document will not detail leak collection systems but they can provide one of the best methods of leak detection and collection. If a leak collection systems includes a geomembrane, you can use geophysical methods to quality assure them. Geophysical testing doesn't replace traditional construction quality assurance (CQA) techniques, but rather provides the ability to test the whole liner. A geophysical survey will not for example, provide information on the quality of materials used or the strength of welds. A survey will (if undertaken correctly) show that no leaks of greater dimension that the sensitivity of the survey exist. Regulators, consultants and operators must consider the CQA system as a whole, balanced against the risk to the environment of a leak of a certain size being present.

The detail in this document supports our general approach to landfill engineering which is detailed in our policy LFE1 – Our approach to landfill engineering.

2.0 Background

Until the early 1990s, quality assurance procedures were based mainly on visual assessment methods, testing welds and on taking spot samples from the body of the liner. A shortcoming of geomembrane CQA techniques is that they do not indicate damage to the membrane that may occur during the placing of the overlying materials. Geophysical testing methods provide a means of testing a membrane after a cover has been placed.

The advent of geophysical systems in the USA and Europe has enabled the testing of large areas of membrane after the placing of the protective layer and drainage media. This type of testing extends the ability of quality assurance engineers to confirm the integrity of a geomembrane. Many geophysical methods are applied to liner integrity such as, ground probing radar and microwave techniques. This document only details electrical resistivity systems, which have proved the most successful to date.

3.0 Mobile surveys

3.1 Mobile surveying – operating theory

The first mobile survey of a landfill in the UK was carried out in 1993. Mobile surveying takes place after a liner has been laid and the protective cover installed. A mobile survey is a one-off test to ensure a liner has not been damaged during installation or the placing of the cover. The system operates by exploiting the insulating properties of polymeric geomembranes. An electrical voltage is passed between two electrodes, a fixed electrode placed in the ground outside the lined area and a moveable set of electrodes within the liner. During a survey, as the moving electrode approaches a defect along a particular grid line, the electrical potential increases gradually. As the electrode passes the defect, the polarity of the signal reverses and then gradually decreases as the electrode moves away from the defect. See the diagram in appendix C1.

To ensure no electrical leakage occurs, a strip of geomembrane should be left exposed around the perimeter of the test area to ensure complete electrical isolation.

Portable monitoring electrodes measure the electrical potential on a grid system. The collected data is then processed and plotted. Where leaks in the geomembrane exist, characteristic signals are produced allowing you to accurately locate, repair and re-tested the affected places.

3.2 Mobile surveying – system capability

The sensitivity of geophysical surveys, that is, their ability to detect a hole of a given size depends on a number of variables. These include the magnitude of the applied voltage, the thickness of the cover material, the spacing of the grid and the conductivity of the materials above and below the liner. The electrical sources used vary form 12v DC batteries to portable AC generators. The voltage is generally amplified to approximately 300v.

Smaller holes have lower cross-sectional areas and higher electrical resistances, therefore in order to achieve a detectable, measurable current, a higher voltage are needed. For a given hole size, the signal strength caused by the leak decreases as the soil thickness increases. Field trials have successfully detected defects as small as 1mm, through 1100mm of cover consisting of 100mm sand, a geotextile and 1000mm of coarse drainage aggregate. Where geotextiles are used as a protective layer above a geomembrane, it's possible the geotextile could bridge the insulation layer around the site. Our experience has shown however that for the system to operate successfully, the soil (above and below the liner) needs to be moist but not saturated. The natural moisture content of most soils is sufficient to conduct an electrical current. If the soil cover is too dry it may be necessary to wet it prior to carrying out a survey. You can use a water bowser and/or spray guns for this. If you haves any doubt about the suitability of the materials, you should carry out a test to demonstrate its viability.

Our experience has shown however that such testing is perfectly feasible. Successful leak location surveys have been conducted over a range of coarse aggregate drainage layers.

The ability of any system used to detect defects should be demonstrated during the survey. We recommend that quality assurance engineers assess the sensitivity of the survey by one of the following methods:

- Place the bare end of a coated copper wire in the ground outside the lined area with the other bare end to the surface of the geomembrane. This will deliver current inside the liner and demonstrate whether the equipment is functioning, and test its sensitivity. You must remove the wire once the testing is complete.
- Deliberately make a hole in the geomembrane at a position unknown to the survey team to ensure that the system is functioning as specified. If you choose this method, make the hole well away from the sump area. Once you've made the hole, firm the geomembrane down against the subgrade to ensure no air void exists below the membrane, as any air void will prevent the electrical current from being transmitted. Replace the cover material once you've made the test hole, then wet the cover soil to ensure it and any geotextile will be conductive. Whether or not the survey team detect it, the test hole must be repaired by experienced personnel and retested. (in accordance with section 3.4) to ensure there are no leaks. The further implication of this is that any holes in wrinkles can't be detected by this method giving greater importance to ensuring that the liner is in intimate contact with the subgrade.

Geophysical surveys have successfully identified leaks in leachate lagoons at several sites in the UK. Lagoon surveys are very sensitive as water is an ideal conductor.

Typically, the lagoons slopes are tested from the perimeter when the lagoon is full. Subsequently, the water level is lowered and the rest of the lagoon is tested with approximately 0.5m of water present. As with soil cover surveys, you must remove or isolate any potential electrical leakage paths prior to conducting a lagoon survey.

At sites where the conductive/protective medium above the liner is composed of the same material as the surrounding area (for example, a sand cover in a sand quarry) holes can be difficult to detect if the cell is not properly isolated. Detecting holes in these circumstances may involve changing the position of the inner and outer electrodes to ensure that all holes have been detected.

3.3 Mobile surveying – preparing the site

a) If the geomembrane is fully covered with a protective/drainage layer, you should expose an isolation strip approximately one metre wide around the perimeter of the survey area. In extreme circumstances surveys have been carried out without this strip, although this makes interpreting the data more difficult.

b) You should examine the soil to ensure they are sufficiently moist to allow current flow. In dry conditions, you may need to position the monitoring electrodes just beneath the dry surface or wet the cover materials using spray guns.

c) Conducting materials near the test area may affect the results; we recommend that, where possible, you should remove all such materials.

d) Isolate potential leak paths such as pipes.

e) Mark the test area with numbered grid lines (using tape or rope), we recommend spacings between 0.5 and 2 metres.

f) Place the electrodes, connected to a suitable power source in the underlying soils outside the test area.

g) Occasionally you may need to undertake testing over a geotextile protector (we don't recommend this, as damage may occur during placing of the cover or drainage layer). Where you must undertake this type of testing, check that the geotextile is thoroughly wetted through to the geomembrane, and that the geotextile is in intimate contact with the geomembrane.

3.4 Mobile surveying - interpreting the data

Voltage readings between adjacent positions, usually 0.5 to 2 metre apart, together with the grid number and distance along grid lines, are collected and fed into an on-site computer either manually or via a data logger.

The computer generates graphs of voltage along grid lines generating a two dimensional plan view showing voltage contour lines. It is also possible to generate a three dimensional output. Examining the output may reveal anomalous readings, not all of which are caused by holes (for example, folds in the membrane, leachate drainage pipes and so on), an experienced operator should be capable of interpreting the data generated. Additional readings should then be taken to verify each anomaly and locate them precisely.

3.5 Mobile surveying - repairs and retests

Soil above a defect should be carefully removed ensuring no further damage occurs. Locate the defect, then mark and photograph it before having it repaired. You must then carry out a retest of a ten metre radius around the defect to ensure that all leaks have been located and repaired successfully.

Ideally, the survey should be carried out while the lining contractor is still on site. This will enable speedy repairs and retests of the affected area without the additional costs of remobilising a survey team at a later date.

3.6 Mobile surveying - working plan and reporting requirements

See Appendix A (report checklist), and Appendix B (working plan checklist)

4.0 Fixed surveying systems

4.1 Fixed systems – operating theory

Fixed Systems work on the same theory as mobile surveying, however a permanent array comprising a grid of wires or electrodes is installed beneath the geomembrane liner. Fixed systems vary in their construction, common examples include:-

a) A network of stainless steel electrodes buried in the soils beneath the liner, connected together by coated or non-coated wire with the various wires connected to a computerised monitoring station, or

b) Stainless steel wires woven longitudinally into the geotextile. Two layers of the geotextile are placed at 90° to one another to form a grid of wires (separated by an insulating geotextile), are then buried beneath the liner. Fixed systems can detect liner defects prior to emplacing waste to prove 'built integrity', as with mobile surveys but they can also monitor operational integrity.

Fixed systems can detect the presence and extent of any leaks when they occur (in a lateral plane) which you can build up into a series of electrical pictures (tomographs) of the subsurface soil resistivity beneath the landfill. It is important to plot such tomographs prior to landfilling to allow subsequent routine monitoring to detect changes.

Experience of fixed systems in the UK is still limited, it is apparent however that they are likely to provide monitoring over at least a period of years. These systems have been used in the USA and Eastern Europe, with the first such system used in the UK installed at a site in the Midlands in 1995. We prefer this type of system to mobile surveying because it remains operational for an extended period of time. Evidence from Europe has indicated that geomembranes can be punctured during their operational life due to the stresses and strains imposed by the waste body.

4.2 Fixed systems - system capability

Fixed systems provide a monitoring facility for a number of years. The service life of the installation will depend on the longevity of the materials. If for example wires corrode or couplings become detached during operation due to leachate attack after a leak the functionality of the system may be affected.

You can use fixed systems in localised high risk areas such as those around landfill sumps or possibly up to the 1m leachate 'tide-line' (if we stipulate a 1m a condition in your permit).

You should decide the extent of the installation on the basis of a risk assessment. You may find a restricted zone useful at sites where leachate control mechanisms are very efficient and you don't expect leachate heads to rise above a specified head.

4.3 Fixed systems – preparing the site

The site preparation your fixed systems will require depends on the individual system you're installing. A number of systems require you to excavate trenches and refill them, paying attention to the compaction of soils to ensure that no differential settlement occurs beneath the liner which might threaten the integrity of the geomembrane. Our experience of fixed systems to date suggests they can be as sensitive as mobile surveys in relation to the hole size they can detect.

4.4 Fixed systems – interpreting the data

Data interpretation for fixed systems is similar to that for mobile surveys, however you'll need a permanent installation on the edge of the site to house the wire terminals.

4.5 Fixed systems - repairs and retests

You can test the system during construction to ensure all the connections are properly made. Once the liner is installed, carry out testing to detect any leaks. If your testing detects any leaks, mark and photograph them for recording purposes, then arrange for them to be repaired.

4.6 Fixed systems – costs

Costs for fixed systems are greater than those for mobile surveys, they also depend on the system you choose. The various system suppliers can provide more details on the likely costs involved.

4.7 Fixed systems - working plan and reporting requirements

See appendices A and B.

Further reading

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- **White C & Barker R** Geophysical leak detection systems for landfill liners: A case history, Proceedings of Polluted & Marginal Land, July 1996.

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- **Environment Agency** (2009) How we assess engineering designs for landfill sites
- **Environment Agency** (2009) Cylinder testing geomembranes and their protective materials.
- **Environment Agency** (2009) Earthworks on landfill sites
- **Environment Agency** (2009) Guidance on using landfill cover materials
- **Environment Agency** (2009) Using geomembranes in landfill engineering
- **Environment Agency** (2009) Using nonwoven protector geotextiles in landfill engineering
- **Environment Agency** (2009) Geophysical testing of geomembranes used in landfills
- **Environment Agency** (2009) Compliance testing earthworks on landfill sites using nuclear density gauges
- **Environment Agency** (2009) Using bentonite enriched soils in landfill engineering
- **Environment Agency** (2009) Using geosynthetic clay liners in landfill engineering.

Appendix A - Report checklist for a geophysical survey mobile surveys fixed systems

Mobile surveys | **Fixed systems**

A description of the system used, including the site tested accuracy

A copy of the specification given to the survey team

Scaled plans accurate to 0.1 m, of the area surveyed. Such plans should be referenced to the national grid and as minimum contain:

- site features, such as roads, weighbridges and so on;
- the survey grid;
- the extent of the liner surveyed;
- a north arrow;
- clearly marked with the site name, survey date and scale;
- all defects found must be clearly marked with individual numbers, the size of the defect and the repair and retest dates.

Referenced and described photographs of the works and defects

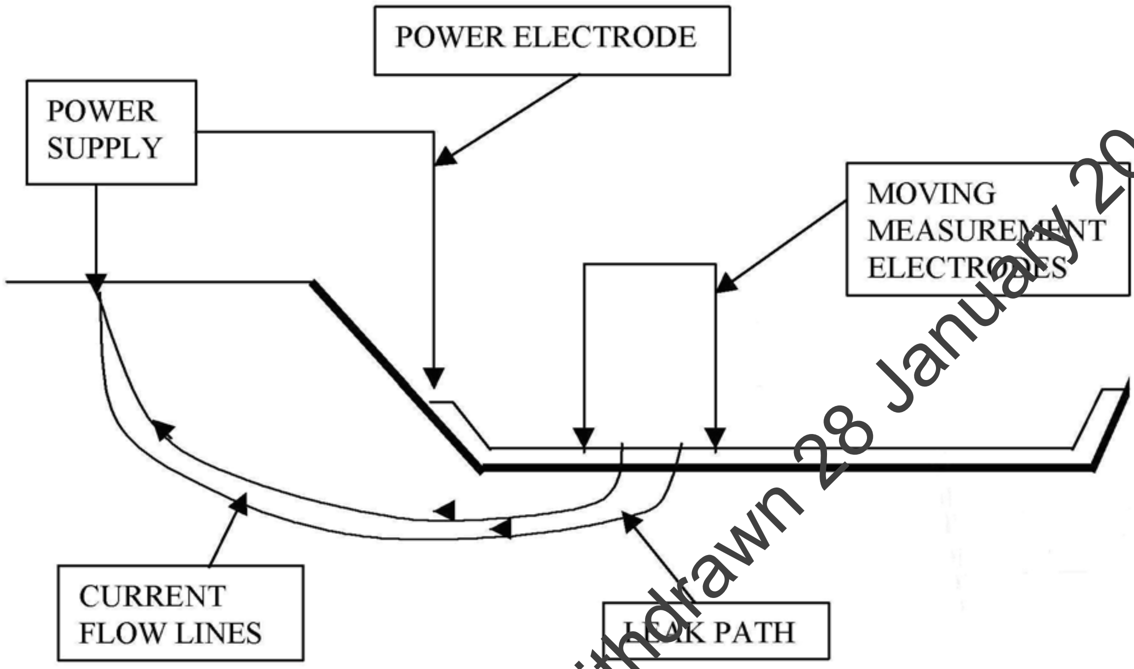
Records of the survey should be supplied in sufficient detail to allow interpretation by a third party in the case of any dispute. This should include the location and electrical potential for every measured point.

The name and experience of the operators must be clearly shown.

Appendix B – working plan checklist for a geophysical survey

Mobile surveys	Fixed systems
1. Name and experience of operator and data interpreter	
2. Name of site and area to be tested	
3. Description of equipment to be used	
4. Method for testing site accuracy	
5. Not applicable	5. Method of installation
6. Not applicable	6. Details of materials to be used and test data related to lifespan
7. Proposed survey layout, line spacing and so on	7. Proposed site layout
8. Examples of expected 'as-built' reports	
9.Not applicable	9. Example of operational report and reporting interval

Appendix C1 – schematic of mobile leak-location survey



Appendix C2 – schematic of a fixed leak-location system