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LFE 2 - Cylinder testing geomembranes and their protective materials

A methodology for testing protector geotextiles for their performance in specific site conditions

ea/br/e/std/v1

Contents

Introduction

This document describes a method for determining the effectiveness of a material in protecting a geomembrane against the long term mechanical effects of static point loads. The cylinder test method tests performance under the conditions likely to be encountered in a landfill site.

This test methodology provides a consistent means of carrying out and reporting cylinder tests. We originally developed this method jointly between a working group of our own regulatory officers and industry representatives, including test houses and geomembrane manufacturers. This update to the guidance has been developed again in association with an industry working group, namely BTTG Testing and Certification, Geofabrics Ltd and Naue Geosynthetics Ltd.

We derived this methodology from a technique originally developed at the University of Hannover. Our pass/fail criteria is less than or equal to 0.25 % strain based upon the maximum average local strain.

The test simulates many of the conditions faced by protector materials used in landfill sites. It applies primarily to non-woven geotextile protectors placed over high density polyethylene (HDPE) geomembranes, as these were the components in the original research. The method also allows for shorter test times and testing increased temperatures.

We recognise this test may also be applicable to other product combinations, however the factors applied during the test must be justified for the products being tested. The test should be conducted using the actual geomembrane, geotextile and aggregate proposed for the site in question. However, experience has shown that testing textured geomembranes can cause problems. For this reason, where a textured product is proposed, the test should be carried out using a smooth membrane of the same density and thickness from the same manufacturer and using the same manufacturing process.

We require that the cylinder test results provided to us for validation purposes are carried out by a laboratory independent of the geotextile manufacturer. These cylinder tests must be performed in a laboratory having UKAS accreditation for the test. In addition, by April 2011, we will also require that the laboratory must have participated in inter-laboratory trials organised and run on behalf of us. These trials will continue on a regular basis post April 2011.

Normative references

This document and the test itself can only incorporate published standards as they currently exist. For this version of the test methodology we've considered the following standards:

- EN ISO 10320 Geotextiles – identification on site;
- ISO 554 Standard atmospheres for conditioning and/or testing – specifications;
- ISO 7619 Rubber – determination of indentation hardness by means of pocket hardness meters;
- BS 1178 Specification for milled lead sheet for building purposes.
- Mass per unit area EN ISO 9864
- CBR Puncture resistance EN ISO 12236
- EN:12588 Rolled lead sheet for building purposes

The application of new or updated standards will only occur once this methodology has been reviewed, rather than automatically when a new standard is issued.

Definitions of strain

The cylinder test differentiates between two different types of strain. These are defined below:

- **Local strain** – expressed as the difference between the deformed length (l_d) of a straight line between two points on either side of a deformation and the undeformed (l_u) between the same two points divided by the undeformed length. See Figure 2 for more information.

$$\text{Local strain} = \left(\frac{l_d - l_u}{l_u}\right) \times 100$$

- **Incremental strain** – the strain for each 3mm segment of the measurement axes through the resulting indentation.

$$\text{Incremental strain} = \left(\frac{l_d - l_u}{l_u}\right) \times 100 \text{ per 3mm segment}$$

- **Average local strain** - expressed as the mean local strain of the two opposing axis of a single indentation on the lead sheet. See figure two where average local strain: (local strain axis A + local strain axis B)/2 = average local strain

Principle of the test

A load is applied through the proposed drainage aggregate and protector material onto a specimen of the proposed geomembrane for a standard time. The local and incremental strains experienced by the geomembrane are measured and recorded. The test is carried out in dry conditions.

Test apparatus

Note: Figure 1 shows the arrangement of the complete test apparatus.

Cylinder

The cylinder used during the test must be of steel construction with a minimum internal diameter of 300mm. It may be formed of sections (bolted together with flange joints) to allow assembly and dismantling without deforming the lead test plate.

Three-point support

Three load cells or pressure gauges support the lower steel plate of the test apparatus. These load cells record the applied pressure through the system to an accuracy of 1%.

The load cells must be calibrated at least every twelve months. You should obtain certificates from your test house detailing the method and results of the most recent calibration.

Lower steel plate

The lower steel plate should have a minimum thickness of 20mm. This steel plate must have a diameter 4mm smaller than the internal diameter of the cylinder. This 4mm gap may have a tolerance of ±1mm.

Dense rubber pad

The dense rubber pad must have a minimum thickness of 25mm and a similar diameter to the lower steel plate detailed above. It must also have a Shore hardness of 50A ±5, determined in accordance with ISO 7619. As hardness may vary with time, the rubber pad must be checked on a grid no greater than 20 mm for hardness at least once every twelve months. You should obtain copies of the records from these hardness tests.

If a pad fails a hardness test at any point on its surface or is subject to permanent mechanical damage, it must be discarded.

Lead impression sheet

The lead sheet must have a thickness of 1.3mm ± 0.1mm. It must be made of grade 3 lead in accordance with BS 1178. Additionally, it must bear the deformation characteristics described in Annex A. As with the lower steel plate, the lead disc must have a diameter 4mm ±1 mm smaller than the internal diameter of the cylinder.

Before the test is carried out, the test house must test the flatness of the lead disc by attempting to insert a 1mm gauge between the lead disc and the rubber pad. If it is possible to insert the gauge, the test should not continue.

Geomembrane

A disc of your proposed geomembrane (see introduction) should be prepared for the test. It's diameter must be similar to that of the lower steel plate. The sample of geomembrane must have a unique reference number and be identified in accordance with EN ISO 10320.

Protective material

A sample of your proposed protective material should also be prepared for the test. It must be fully described and bear a unique reference number.

Aggregate

You should provide your test house with a minimum of 50kg of a representative sample of the actual aggregate you plan to use on site.

Separator disc

This should be a material disc with a diameter similar to the internal diameter of the cylinder. The purpose of this disc is to prevent sand from migrating into the drainage aggregate below.

Sand

This element of the test apparatus must be formed of at least 50mm of builder's sand.

Upper steel plate

The upper steel plate must be of 20mm minimum thickness with a diameter 4 mm smaller than the cylinder with a ±1mm tolerance.

Applied load

A means of supplying the specified load for the duration of the test.

Timing device

A timer with an accuracy of one minute must be available for the duration of the test.

Temperature and humidity recording device

A temperature measuring device to ensure an accuracy of ±2°C must be available to measure the test environment throughout the test. A humidity measuring device to ensure an accuracy of ±5% must be available to measure the test environment throughout the test.

Deformation measurement

There must be a means of measuring both the deformed and undeformed length of any depression in the lead sheet. It must be possible to simultaneously measure both horizontally and vertically with an accuracy of ±0.01mm. See Figure 2 for more information.

Note

Where a cylinder liner is used to reduce sidewall friction, this must be recorded in the final report.

Test specimens

The samples of both the geomembrane and the protective material must be taken from the materials supplied to the test laboratory.

The testing laboratory must prepare the test specimens from the materials you've provided. The specimens should be cut from the sample materials. They must be circular with a diameter similar to that of the lower steel plate.

If the sample material has different characteristics on each face, you must specify which face should be placed facing upwards during the test. This arrangement must be recorded in the final test report.

The test apparatus and test specimens must be left to condition for at least 24 hours.

Test procedure

The test procedure consists of three main stages, these are:

- Preparing the test;
- Carrying out the test;
- Completing the test and calculating the results.

Preparing the test

Follow the steps in the table below to prepare the test.

Step	Action
1	Measure the mass per unit area (EN ISO 9864) and thickness @ 2KPa (EN ISO 9863-1) of the actual geotextile specimen used in the test. Also prepare one specimen for a CBR test taken immediately adjacent to the cylinder test specimen. Test this one specimen in accordance with the procedure detailed in EN ISO 12236. Measure the thickness of the geomembrane to be used in the test.
2	Assemble the apparatus and place the rubber pad and the lead sheet. Use the rubber pad as a tray to carry the lead sheet and avoid handling damage.
3	Photograph and examine the geomembrane and the protective material specimens and record and report any marks, tears, nicks, scratches or other signs of distress. Place them in their respective order in the cylinder.
4	Thoroughly mix the whole of the supplied aggregate. Build up the aggregate in three layers in the cylinder. The minimum depth of the aggregate should be 150mm. If the depth is less than this, include it in the report. Placing the aggregate can influence the result of the test. Therefore, avoid compacting the material in the cylinder. The placing of three layers is intended to avoid any potential for bridging or voids.
5	Check the test conditions are as follows: ▪ Conduct the test in dry conditions at a temperature of 20˚C ±2˚C ▪ 65% $\pm$5% relative humidity.
6	Calculate the required pressure a) For HDPE - Calculate the expected maximum overburden pressure due to the depth and density of waste and restoration materials. That is, (depth of waste x the waste density x acceleration due to gravity) + (depth of restoration materials x the density of restoration materials x acceleration due to gravity). Multiply the result of this calculation by the following factors. These factors have been experimentally derived from simplified extrapolations of the deformation behaviour of HDPE materials. ▪ 2.25 times the overburden pressure for tests at 20^0C and 1000 hours; ▪ 2.5 times the overburden pressure for tests at 20^0C and 100 hours. For example for a landfill with 20m of waste and a waste density 1000kg m^{-3} and a 100 hour test at 20^0c the test pressure would be calculated as follows: 20 x 1000 x ($9.81x10^{-3}$) x 2.5, giving a test pressure of 490.5 kN m^{-2} b) For other protective materials and geomembranes - Calculate the expected maximum overburden pressure as above. The experimental factors outlined above have not yet been developed for other liner materials, therefore you should adopt a cautious approach. We recommend therefore that test pressures should be agreed between the various parties in advance.

Carrying out the test

Follow the steps in the table below to carry out the test.

Step	Action
1	Gradually increase the pressure up to the calculated test pressure (see above) over a period of one hour. Once the test pressure is reached, start timing the test and maintain the full test pressure for the duration of the test. The pressure recorded by the load cells should be maintained within a range of $\pm$5% of the calculated design load.
2	As a minimum, check the pressure every five minutes for the first hour, every 10 minutes for the second hour, every hour for the third to sixth hours and every 24 hours thereafter. If the pressure falls outside the specified range, the test should be aborted. There may be circumstance where continuing the test could provide useful information. If this is the case, contact the test specifier before aborting the test.
3	As a minimum, record the temperature and humidity once every 24 hours.

Completing the test and calculating the results

Follow the steps in the table below to complete the test.

<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Carefully dismantle the test apparatus within one hour of the test ending. Recover the protective material, the geomembrane and the lead plate taking care to cause no damage to any of the specimens.</td></tr>
<tr><td>2</td><td>Visually examine the protective material and record any changes in its condition, including cuts, holes and any other signs of distress.</td></tr>
<tr><td>3</td><td>Similarly, examine the geomembrane and record and report any nicks, scratches, marks or other signs of distress.</td></tr>
<tr><td>4</td><td>Photograph a representative sample of the stone used in the test with an appropriate scale.</td></tr>
<tr><td>5</td><td>Measure the deformation as follows; 24 hours time limit
<table>
<tr><th>Step</th><th>Action</th></tr>
<tr><td>1</td><td>Examine the lead sheet and select the five indentations which have the greatest deformation lengths, taking into account both the depth and the steepness of the sides. Do not select deformations within 25mm of the sheet edge.</td></tr>
<tr><td>2</td><td>On each deformation, mark two axes at right angles to each other.</td></tr>
<tr><td>3</td><td>Using the deformation measuring device (figure 2), start at the edge of the deformation and work along one of the axes. Determine the vertical displacement correct to 0.01mm at 3.0mm ($\pm$0.2mm) horizontal intervals to the edge of the deformation. The edge of the deformation is defined as a point where two consecutive readings 3mm apart have a vertical height difference of less than or equal to 0.06mm or where the vertical height difference starts to increase again due to an adjacent indentation.</td></tr>
<tr><td>4</td><td>Repeat the measuring procedure along the second axis. Then repeat the whole measuring procedure until you've measured all ten axes.</td></tr>
</table>
Measuring the deformation must be completed within 24 hours of removing the test load.</td></tr>
</table>

Calculating the results

The test laboratory will most likely carry out all the required calculations. However, for completeness the calculation method is outlined below.

Using the measurements of (detailed above) the undeformed and deformed lengths, use a series of Pythagorean calculations to calculate the incremental strain on each segment of the indentation on the lead disc.

For each axis, calculate the local and incremental strain correct to 0.01%. The strain results for the three indentations with the highest mean strain values of both axes are the values which should be included in the final report.

Compiling the test report

Your test laboratory should prepare a test report for you. You should let them know beforehand the details you expect to be included.

The test report should as a minimum include the following information:

Item	Details
a)	The name and address of the laboratory who conducted the test.
b)	Reference to this methodology, and a statement the test they've carried out meets its requirements. Any deviations from the procedure must be recorded.
c)	Identification of the geomembrane and protective material samples, including their unique reference numbers.
d)	Record of the test conditions (as above) and the sample conditioning (see Test specimens)
e)	Note of which side of the geomembrane or protective material was tested (if the two sides of the sample are different).
f)	Confirmation the lead sheet complies with the test apparatus specified and that the deformation characteristics comply with the requirements of Annex A.
g)	Note of the use of any friction reducing liner to the cylinder sides (as above) and the pressure used during the test.
i)	Duration of the test and details of the temperature and humidity throughout.
j)	Record of any physical damage or changes to the geomembrane and the protective material. (see Test specimens and Test procedure).
k)	The calculated local and incremental strains measured and the maximum average strain in the metal sheet (see Measuring the deformation above).
l)	The mass per unit area and thickness of the geotextile used in the test
m)	CBR of the geotextile adjacent to the test sample
n)	Thickness of the geomembrane
o)	Photographs taken of the aggregate.

Annex A – method for determining the deformation characteristics of a lead sheet

In the original development work for the cylinder test, we made the choice of 'organ pipe' sheet metal with the intention it would not significantly contribute to the strength of the system. Subsequent inter-laboratory comparisons have shown that sheet metal materials with similar descriptions have performed very differently. Therefore it's necessary to demonstrate that the proposed metal sheet complies with the following deformation requirements before carrying out the cylinder test. Use the following method to confirm the lead disc you intend to use is satisfactory.

Apparatus

Lead impression sheet

A 1.3mm ± 0.1mm thick, minimum 100mm ±2mm diameter disc of grade 3 lead to BS 1178. As per Test apparatus above.

Dense rubber pad

25mm minimum thickness rubber pad with a minimum diameter of 100mm as in Test apparatus above. It must also have a Shore hardness of 50A ±5, determined in accordance with ISO 7619. As hardness may vary with time, the rubber pad must be checked on a grid no greater than 20 mm for hardness at least once every twelve months. You should obtain copies of the records from these hardness tests.

If a pad fails a hardness test at any point on its surface or is subject to permanent mechanical damage, it must be discarded.

Indentation measurement

Means of measuring the depth of the indentation to an accuracy of 0.01mm.

Standard laboratory compression apparatus

Steel Ball

A 25mm ±1mm diameter spherical steel ball

Test procedure

Step	Action
1	Prepare the test apparatus in the same temperature and humidity conditions as the main cylinder test.
2	Measure the thickness of the lead sheet to an accuracy of 0.01mm.
3	Place the lead sheet on the dense rubber pad.
4	Using the standard laboratory compression apparatus, apply a load onto the surface of the lead sheet using the 25mm diameter spherical steel ball. Use a vertical movement rate of 1mm per minute until a load of 250 N is reached. Immediately remove the load, there must be no holding period.
5	Measure the maximum depth of the indentation to an accuracy of 0.01mm.
6	The depth of the spherical indentation must be greater than 2.5mm for the lead sheet to be acceptable for use in the main cylinder test. If the lead sheet fails this test, do not proceed with the main cylinder test.

Figure 1 Arrangement of test apparatus

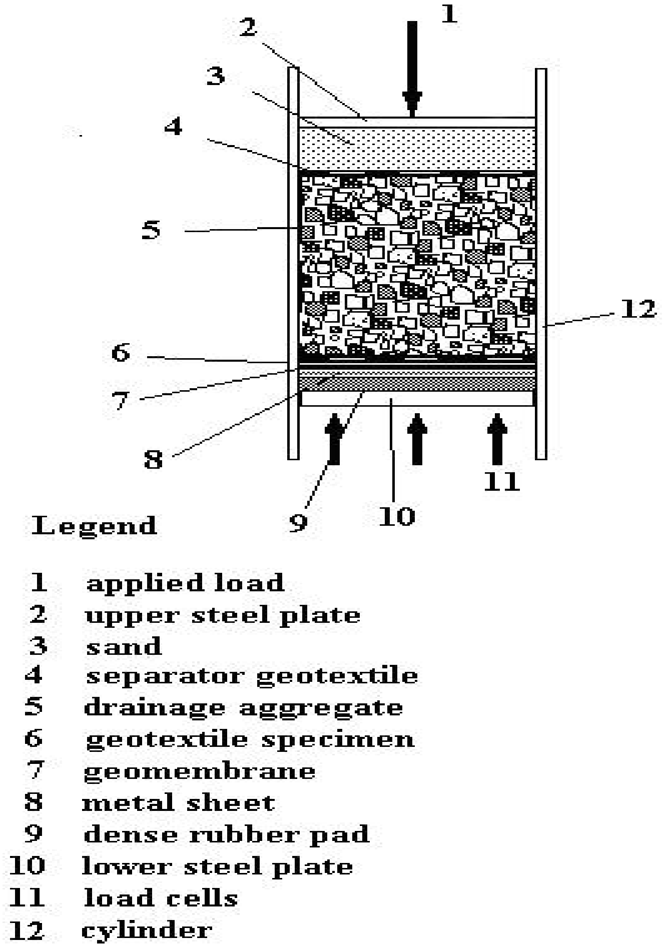

Figure 2 Measuring deformation