LFE7 - Using nonwoven protector geotextiles in landfill engineering

Contents

1.0 Introduction

The Landfill by Design approach (see LFE1 -Our approach to landfill engineering) outlines our expectation that technical standards in landfill engineering should be based on site specific risk-based criteria backed by sound civil and geotechnical engineering and scientific calculations.

This guidance does not cover woven geotextiles, as they are not commonly used as protectors.

One of the reasons we have produced this guidance is to address the construction quality assurance (CQA) of geotextiles with our cylinder test methodology. The cylinder test is a performance test to be used during the design process, rather than the CQA process.

2.0 Material properties

Geotextiles are made from polymers derived from crude oil to which various additives are added to create a thermoplastic material. This thermoplastic material is initially formed of small beads, which are then melted and extruded as fibres. Differences in the original polymer and the manufacturing process can lead to significant variations in the properties of the final material. You must not assume that all geotextiles are equally suitable.

The majority of protector materials are manufactured from polypropylene staple fibres. Any other materials need to be justified on a site specific basis and include pH and the temperature of the leachate.

We treat geotextiles made from recycled materials with caution. There is no guarantee the desired material properties are uniform throughout the length, breadth and thickness of the material. As such, they should be avoided in landfill engineering. Recycled in this sense refers to material that has been derived from off-specification material during the manufacturing process or material that at some stage has been incorporated into another product.

These geotextiles may be used if we are confident that the desired material properties are uniform throughout the product and the manufacturer can supply quality control data to confirm this. In addition to design testing, the manufacturers' quality control programme and the construction quality assurance programme should be structured to demonstrate the desired properties are consistently achieved throughout the product. This should be demonstrated both in relation to properties relating to durability as well as those used for standard quality control. Proof of durability should be demonstrated. The durability should exceed 100 years.

3.0 Design

The objective of any liner protector is to ensure that the stresses and strains encountered during the construction phase and operational life of a site pose no significant risk of damage to the geomembrane. Designers must assess the potential for stresses and strains in the geotextile. The table below outlines the issues designers must consider. This table is not exhaustive, it simply lists the common issues which apply to most landfill sites.

Environment	Issue
Physical	The likely stresses and strains imposed during the construction period. The likely stresses and strains imposed by settlement and movement of the waste body. The likely stresses and strains imposed by the materials placed in contact with the geotextile, particularly the drainage blanket stone. The duration of exposure to ultraviolet light. The likely temperatures expected adjacent to the geotextile and whether these may have a damaging effect upon the material properties in any way. The interface friction angles between the materials around the geotextile and the geotextile itself, particularly on slopes. The overall stability of any slopes. The overall stability of the site, that is, the likelihood of settlement or differential settlement.
Chemical	The likely chemical interactions between the geotextile and the leachate/wastes in the site. There should be little or no interaction. The likely interaction between the geotextile and the material around the geotextiles. There should be little or no interaction. The polymeric structure of the geotextile itself and whether it will be prone to degradation which would affect its ability to protect the liner. The polymeric structure should be such to cover the predicted life of geotextile and the geomembrane. The effects of mineral precipitation on the geotextiles performance.
Biological	The effects of microbial growth on the polymer of the geotextile. The effects of microbial growth on the characteristics of the geotextile.

3.1 Factors of safety

Having developed a material specification based on the issues above, designers must then apply an additional factor of safety to cover unknown factors which may develop during the life of the site. Factors of safety may be introduced at a number of stages in the design stage (For example, as a result of using the cylinder test). It is essential that the various factors applied to the design are clearly stated and explained. Over factorising could lead to unnecessarily high specifications being required.
In general we recommend a factor of safety between 2 and 3.

At this point, designers should decide a material specification, select a geotextile from those available and forward the design (including any assumptions, factors of safety, justifications and material specifications) to us for assessment.

To avoid any abortive effort or unnecessary cost, designers should submit their plans before the material is purchased and arrives on site. Once we agree the material specification (this must have passed a cylinder test in accordance with LFE2 cylinder testing geomembranes and their protective materials), this becomes the material specification that must be complied with. If the material fails to meet the specification in any way, designers must seek further information on the cause of the fault. They must carry out a technical assessment on the significance of the failure and the possibility that it may be present in other parts of the material.

3.2 Design Testing

There are a number of methods available to designers to demonstrate that a nonwoven geotextile protector will perform as predicted for the lifetime of a site.

These include:

Laboratory Testing of geotextiles is required. Determining the frictional properties of the materials and the interface friction angles can be useful and utilised in the design process. In addition it is necessary to carry out an ***Environment agency cylinder test*** *(see* LFE 2*)* to determine the the geotextiles ability to protect a

geomembrane from long term stress cracking. This is an accelerated performance test undertaken under laboratory conditions with the geomembrane and leachate drainage stone to be used at the site. A number of factors are built into the test methodology that that allow it to be undertaken at 20˚C and over 100 hours. A telltale lead plate is placed beneath the geomembrane, which is assessed at the end of the test for indentations. The worst three indentations are reported by the laboratary, with the pass/fail criteria being that the average local strain of any indentation is ≤0.25%. The cylinder test is often the principle means of selecting an appropriate protection material, it is therefore necessary to establish the properties of the material being cylinder tested in order to ensure conformance testing is conducted against material of equal physical performance.

The manufacturer's data (which should have been collated over a period of time) can often demonstrate the effectiveness of a material. However, we will treat specification sheets showing the results of various tests with caution and view them as only a summary of various data. For us to place confidence in such data, our officers need to spend time considering how and in what form the data has been presented. In the UK, European tests (normally prefixed with BS EN or CEN) should be used in preference to all other test types. Each test method has a protocol for calculating and presenting the results of a test; these may be averages, minimum and maximum results or minimum average roll values.

There have been several examples of manufacturer's data sheets being used to specify material with the figures from these sheets being included in the CQA plan as minimum figures. Subsequent conformance may then fall below these levels while still being within the manufacturer's statistical product distribution. This confusion arises due to the differences between the minimum design requirements for protection and the fact that data sheets (in conforming to standard reporting requirements) rarely show minimum values.

It is therefore essential that a manufacturers CE declaration is used in conjunction with a data sheet to establish tolerances prior to a product being incorporated within the design. The designer should always review the manufacturers tolerance limits along with the mean data supplied on standard product sheets to ensure that values do not fall below any minimum design requirements.

4.0 CE marking & manufacturer's quality control

Since the late 1980's the CEN TC 189 committee has standardised testing methods and procedures to encourage continuity and consistency across the industry. Since the early part of 2002 it has become a mandatory requirement to CE mark geotextile and geotextile-related products to demonstrate compliance with the European Construction Products Directive (Council directive 89/106/EEC) (CPD). Since October 2002, it has been a mandatory requirement to CE mark geotextiles within the majority of EU member states. The CPD provides for four main elements:

- a system of harmonised technical specifications
- an agreed system of attestation of conformity for each product family
- a framework of notified bodies
- the CE marking of products

The CPD does not aim to harmonise regulations, but the methods of testing and the way in which manufacturers of products report on their performance values and the method of conformity assessment.

CE marking is a *passport* that enables a product to be legally placed on the market within any member state. *CE marking does not mean that the product is suitable for an end us*e. It simply means that the manufacturer has complied with the regulations set out within the CPD and that it must report on the harmonised declared values set out within the standards.

For geosynthetics, there are several standards published by CEN TC 189 for CE marking based on product applications. EN 13257: Geotextiles for solid waste disposal is the application standard that considers the use of geotextiles and 'geotextile related products' for membrane protection in landfill engineering and identifies the characteristics that a manufacturer should report on a CE declaration based on a particular function. The testing that needs to be performed on a product depends on the function that the product is required to perform within the application. The five functions are set out within EN ISO 10318; these are filtration; separation; reinforcement; protection and drainage. Table 1 within EN 13257 identifies the relevant characteristics that a manufacturer must publish on a CE declaration in line with specific functions. The 'harmonised characteristics' within the table are those which a manufacturer is required to publish on a CE declaration, although the table identifies other characteristics which a designer may wish to consider.

An accrediting body audits the levels of control within the manufacturing process -The manufacturer is then issued with a certificate of factory production control under the guidelines identified within the EN application standards. The accrediting body should then perform regular checks on the manufacturer to ensure that the system is functioning adequately. A manufacturer is required to publish a CE declaration once a product has been CE marked. The declaration identifies properties and 95% confidence limits relevant to the areas of application and functions highlighted. It also contains a durability statement.

A manufacturer must supply a CE declaration for product delivered to site in accordance with EN 13257 (identified within this report for this application). The values and 95% confidence limits should then be used for evaluation of conformity with the specification in accordance with CEN/TR 15019: On-Site quality control. It must be noted that not all reported characteristics are suitable for conformity testing, and that some test data must be supplied by the manufacturer.

4.1 Durability Data (Annex B – EN 13257)

Within Annex B of EN 13257 there is guidance on the testing that is required in order to make an assessment of the long-term durability of the product. For Polypropylene geotextiles the tests that are required are:

Determination of resistance to weathering (UV)	EN 12224
Determining the resistance to liquids (acids & alkalis)	EN 14030
Determination of resistance to oxidation	EN ISO 13438

The results of these tests will determine the durability statement that the manufacturer publishes on its CE declaration, of which there are various options. Manufacturers may be expected to provide evidence of testing performed to assess long term durability.Some manufactuers may have conducted additional durability studies in addition to the requirements laid out by the CE marking system. These additional durability studies will often be considered by designers, especially in sites where there are harsh environmental conditions. It should be noted that for a range of products which are identical except for mass per unit area, the manufacturer will often test the product with the lowest mass and use these results for the entire range. It should also be noted that these tests are not normally suitable for conformance testing and that such data should be provided by the manufacturer.

4.2 Manufacturer's quality control data

It is essential that all of the material delivered to site complies with the agreed specification. The quality of the product plays a significant role in the degree of protection afforded by the geotextile. Your design report should include information from the manufacturer, on the nature (test types, test frequency, quality standards) of the quality control undertaken on the material in the factory.
For needlepunched products the manufacturing process uses banks of thousands of needles some of which break during the process, this means that pieces of steel needle can be incorporated into the product which could, if not detected and removed puncture the geomembrane on installation. Products should therefore be tested in the factory to detect needle fragments and these should be removed prior to the product leaving for the site. Only use products that are inspected to such an extent that the risk of needles being present within the product can be considered as negligible and thus needle free.

4.3 Product Packaging & Identification

Each roll of geotextile delivered to site must have a label complying with EN ISO 10320 affixed to it. An EN ISO 10320 label should detail the following:

a	The manufacturer (ideally including their address and telephone number)
b	Product identification (product name, type and production plant location)
c	The geotextile roll number
d	The roll length and width in metres
e	The roll weight in kilograms
f	The polymer type

Geotextiles shall be delivered to site in packaging, which will protect the product from damage during handling, storage. Packaging must be suitable to protect the product from UV degradation. Product must be kept in appropriate packaging until such time that it is required for installation.

The geotextile shall be clearly and indelibly marked with the product name and type. The marking shall be easily legible and marked for example along the edge of the roll at regular intervals. The marking should be repeated at regular intervals no greater than 5 metres apart.

5.0 Handling and Installation issues

Geotextile protectors must be carefully handled and stored in such a way that the material properties are not adversely affected. Storage should be on a flat, free draining surface. The geotextile rolls should be delivered and stored in light-tight wrappings to protect the material from ultra violet degradation. Geotextile should be stacked not more than five rolls high and no other materials shall be stacked on top.

To prevent installation damage the geotextile must be installed in such a way that any potential for damage is minimised. Care must be taken with any blades or sharp objects to ensure the geomembrane is not damaged.

Adjacent panels should either be hot air welded or overlapped depending on the design requirements. Welding may prevent the overlying drainage stone migrating under the liner protector which could damage the liner. In situations where settlement may occur, overlapping can be used, using the predicted settlement to determine the degree of overlap. On basal and sidewall liners, where predicted settlements are minimal then cross slope overlaps of 300mm and down slope overlaps of 500mm are common to accommodate any movement caused by placement of the drainage layer. Best practice dictates protector geotextiles should be overlapped and tack welded (using hot air) to hold the material in place. Caution must be exercised to ensure that any welding does not affect either the protection ability of the geotextile or the integrity of the liner.

6.0 Construction quality assurance

Quality assurance has a role to play in all aspects of landfill engineering. Whilst QA techniques don't guarantee works have been carried out in accordance with the specifications, they should give confidence that the following requirements have been met:

i) Effective mechanisms are in place to ensure the construction of the engineered systems will be to the standards and specifications agreed with the Environment Agency and that quality materials and workmanship have been used;
ii) The design, construction and quality assurance processes are well documented provide public confidence in the works.

Independent, third party construction quality assurance provides a level of confidence that the above requirements have been met. Where containment systems are specified in an environmental permit, we will require validation by a suitably qualified and experienced independent engineer that the specified works have been carried out to the agreed standards.

CQA testing may only be undertaken at laboratories that have UKAS accreditation for the required Tests. Accreditation is only given for individual tests so it's worth checking the laboratory has accreditation for all the tests you require.

6.1 Construction quality assurance plan

With regard to non-woven geotextile protectors, the CQA plan must contain the following information:

a	A summary of the geotextile manufacturer's, the fibre supplier's and polymer manufacturer's quality control procedures with a list of characteristics of the material
b	Records of the delivery, handling and storage of the geotextile on site prior to installation
c	Details of the conformance tests to be undertaken by the CQA engineer when the geotextile is delivered to the site
d	Rejection criteria for the geotextile. This will normally be performed in accordance with the accompanying CE documentation and relevant application properties (see section 6.2)

e	The remedial action to be taken in the event of non-compliance with any part of the specified criteria
f	The installation and jointing techniques
g	Procedure for inspecting, testing and sampling joints if appropriate
h	Rejection criteria of the laid geotextile if test results fail
i	Records of the source roll for each panel should be recorded along with the time/date of installation
j	The proposed level of supervision and quality control
k	The proposed format and contents of the validation report (see section 7.0)
l	Procedure for liaising with the Environment Agency

Our staff will visit the site on a regular basis during installation to monitor the implementation of the CQA plan, this will provide them with a working knowledge of the structure. It will also allow them to pick up any faults not noticed by the CQA staff. However, the responsibility for establishing and implementing the CQA plan remains with the permit holder.

Your CQA engineer must keep a daily log recording, where appropriate, the following information:

Records of the delivery, handling and storage of the material
Weather conditions and whether the works are being undertaken within the weather windows specified within the working plan
Periods of on-site supervision by CQA engineer
Testing procedure and reports of field tests
Remedial action taken in the event of test fails
Personnel on site
Contact (site visits, phone calls) by regulatory or other parties interested in the construction
Any other matters detailed in the CQA plan

If you need to deviate from your CQA plan, you must first receive approval from us for your new plan. Similarly, you must report any deviation from your contractor's method statement to us.

Many problems have been encountered in the past due to differences between the agreed CQA plan and the contract documents. Therefore, we strongly recommend you make every effort to avoid such discrepancies.

6.2 Conformance testing

Conformance testing must form part of the overall CQA. It is undertaken to provide confidence the geotextile installed at the site has the same properties as the geotextile specification we've agreed and that the agreed properties are consistent across the whole of the geotextile.

The following should be completely checked and documented by the CQA engineer:

The product marking and the information affixed to the geotextile is in accordance with EN ISO 10320 (see section 4.3).
The CE mark is affixed to each roll along with the accrediting bodies number.
The relevant CE declaration in line with EN 13257 is available, and the reported values and tolerances are in line with the requirements of the design specification.
The conformance testing performed by the laboratory is performed in a laboratory that is UKAS accredited for each individual test.
All conformance testing is correctly evaluated against the requirements of the design specification.

6.2.1 Sampling for evaluation of compliance with the design specification

For sampling, EN ISO 9862 should be applied, except that samples should be taken not less than 5m from the end of the roll in machine direction and over the full width of the roll in the cross machine direction. The location of each sample should be described exactly. Each sample should be marked clearly with the manufacturers name, product identification and roll/batch number.

6.2.2 Evaluation of conformity by a simplified procedure

A delivery lot is considered to fail if one or more of the samples tested do not meet one or more of the declared values on the CE declaration or relevant applications properties.
The supplier may choose to replace the rejected lot or to carry out further testing (in accordance with 6.2.3) on new samples from the product delivered to the site. The results obtained on the previously tested samples should be included in the evaluation.

6.2.3 Evaluation of conformity by statistical procedure

This evaluation may be used, if there are five or more samples taken from the site.

The lot is accepted when:

- All the values measured are within the design specification

  or

- If one or more of the values measured are outside the design specification then perform the following calculation:

  - $(X - 1.645 * s) \geq Q_{min5\%}$ (lower limiting 5%-Quantile in case of minimum value) and/or
  - $(X - 1.645 * s) \leq Q_{max5\%}$ (upper limiting 5%-Quantile in case of maximum value)

Where:
X = mean value of the test results of the samples
S = standard deviation of the test results of the samples
$Q_{min5\%}$ = lower limiting quantile = lower specification value (in this case 5% nonconforming)
$Q_{max5\% =}$ upper limiting quantile = upper specification value (in this case 5% nonconforming)

Table 1: Suggested CQA frequencies for non-woven geotextile protectors

Material property	Test method	CQA test frequency
Physical:		
Thickness under 2 kPa	EN ISO 9863-1	1/2500 m^2 or part thereof
Mass per unit area	EN ISO 9864	1/2500 m^2 or part thereof
Mechanical:		
Puncture resistance	EN ISO 12236	1/6000 m^2 or part thereof
Cone drop	EN ISO 13433	1/6000 m^2 or part thereof
Wide width tensile properties	EN ISO 10319	1/6000 m^2 or part thereof
Tensile test for joints	EN ISO 10321	As required

a) Table 1 is provided for guidance. Testing frequencies should reflect the confidence in the material and the amount of quality control exercised by the manufacturer. The frequencies in table 1 would be those for a product with good MQC (i.e. a test frequency similar to that above).

b) The CQA Engineer should instruct further testing as necessary in order to maintain the quality of the geotextile or where additional testing for other parameters is relevant to the design and/or installation.

Any geotextile that fails to meet the requirements of the CQA plan should either be excluded from the permanent works or be reported to the Agency together with a technical assessment by the CQA Engineer of its significance and any remedial actions considered necessary. Any geotextile laid prior to the receipt of test results shall be at your own risk.

7.0 Validation report

The validation report presents the final ‘as built’ record of the works and acts as the permanent record we hold. It must provide a comprehensive record of the construction and be in such a form that it can be clearly understood, particularly in terms of the technical detail. The information in the validation report should mirror the agreed CQA plan and include all information relevant to the construction.

The following information must be included in the validation report as a minimum:

a	All of the information required in the CQA plan and other sections of this guidance
b	The results of all tests (passes and failures including remedial works and testing of remedial works related to the original failure)
c	Weather conditions
d	Delivery of materials
e	Plant and labour
f	Roll numbers deployed
g	Panels installed
h	Areas of non-conformance
i	Repairs
j	QA installation checklist
k	Records of site meetings
l	Progress photographs
m	Any other relevant information
n	As built drawings (see below)
o	Written confirmation by the CQA Engineer that all the details in the agreed working plan have been complied with and that in their opinion the installation will operate successfully for the predicted site lifetime

The as-built drawings must detail the following:

a	construction details including levels, contours and slope angles
b	locations and identification marks of each panel
c	locations of damaged/repaired areas
d	locations of samples
e	locations of penetrations

Annex A – Model specification template for polypropylene products.

Geotextile to be used to protect a geomembrane at the base of a landfill

1.	The function of the Geotextile is membrane protection at the base of a landfill. The geotextile shall be manufactured under factory production control guidelines set out within EN 13257; Geotextiles and geotextile related products – characteristics required for use in solid waste disposals. The manufacturer must be able to supply accompanying CE documentation upon request. The functional characteristics and relevant test methods to this specific condition of use are identified below:
2.	The geotextile shall have the following properties:

2.1 Physical Properties:				
Polymer type:	Prime quality polypropylene fibre (UV stabilised) with no post consumer fibres			
Fabric construction:	Nonwoven fabric manufactured from mechanically entangled fibre			
	Approved test method	Units	**Typical mean value**	**Tolerance**
Mass per unit area[1/3]	EN ISO 9864	g/m^2		-20%
Thickness @ 2kPa[1/3]	EN ISO 9863-1	mm		-20%
2.2 Mechanical Properties:				
Static puncture strength (CBR)	EN ISO 12236	kN		-10%
Push-through displacement	EN ISO 12236	mm		n/a[1]
Tensile strength (md/cmd)	EN ISO 10319	kN/m		-10%
Tensile extension (md/cmd)	EN ISO 10319	%		+/- 30%
Dynamic-perforation resistance	EN ISO 13433	mm		+ 3mm
Protection efficiency[2]	EN ISO 13719	kN/m^2		n/a

2.3 Durability (according to annex B: EN 13253)*:			
Resistance to weathering @ $50MJ/m^2$ radiant exposure[2]	EN 12224	Retained strength	80%
Resistance to oxidation (100 years)	EN ISO 13438	Retained strength 56 days	50%
Resistance to liquids	EN 14030	Retained strength	50%

1. To be used at the discretion of the Engineer and property not used as part of harmonised testing within EN 13257
2. 1-4 months UV exposure depending on location/season
3. Property can be used at the discression of the designer where required

** Durability test data can be supplied by the manufacturer – test frequency must not exceed 3 years.*
** Manufacturer may use alternative means of assessing oxidation to achieve 100 years.*

3.	The above geotextile is specified as an initial estimate for use with typical stone. It is a requirement that a cylinder test should be carried out prior to installation of the geotextile and stone in accordance with the Environment Agency *Standard:* Cylinder testing geomembranes and their protective materials: A methodology for testing protector geotextiles for their performance in specific site conditions. A report must be provided in accordance with the cylinder test guidance above. Laboratory accreditation to ISO 17025 alone is not acceptable. Testing must be performed using site specific aggregate and membrane. For HDPE membrane the **maximum** allowable strain value shall be 0.25% on any individual indentation.
4.	Geotextiles shall be delivered to site in packaging, which will protect the product from damage during handling, storage. Packaging must be suitable to protect the product from UV degradation. Product must be kept in appropriate packaging until such time that it is required for installation. The geotextile shall be clearly and indelibly marked with the product name along the edge of the roll at regular intervals no greater than 5m. The labelling shall clearly identify the product supplied in accordance with EN ISO 10320: Geotextile and Geotextile related products – Identification on site.
5.	The geotextile manufacturer shall provide production test certificates on mechanical properties at the rate of one set of tests per $6,000m^2$ delivered to site and a minimum of one set per contract. Test methods employed shall be in accordance with the above specification. Certificates relevant to a full delivery of geotextile, identifying each roll, shall be furnished to the Engineer prior to that batch of Geotextile being incorporated in the works.

6.	The rolls of geotextile shall be stored on level ground. It is suggested that they are stacked not more than five rolls high and no other materials shall be stacked on top of the geotextiles.
7.	The geotextile shall be laid and installed in the positions and to the line and levels described on the drawings. Construction plant must not operate directly on the geotextile. When placing drainage material, delivery and excavation plant shall operate on a minimum layer of 1m of drainage material.
8.	Joints shall be formed by overlapping by a minimum of 300mm (500mm on downslope overlaps). The contractor should satisfy the Engineer that no material can migrate between layers at the overlap. Alternatively the joint may be reduced to a minimum of 100mm and continuously jointed by the use of an approved jointing technique.
9.	On site quality control should be performed in accordance with CEN/TR 15019. Test specimens should be taken every 6,000 m^2 with a minimum of 1 test above 1000 m^2 For sampling EN ISO 9862 should be applied, except that samples should be taken not less than 5m from the end of the roll in machine direction and over the whole width in the cross machine direction. The location of the sample should be described exactly. For evaluation of conformance, statistical procedure should be used in line with section 5.2 of CEN/TR 15019: 2004.
10.	The following definitions shall apply when considering test results: A s*et of test results* shall be those results derived from specimens cut from one sample. The *mean value* for any set of test results shall be the arithmetic mean of that set of results. The *characteristic value* is the value below which not more than 5% of the test results may be expected to fall. This represents the value at 1.645 standard deviations below the mean value