Geosynthetic interface shear resistance testing

LANDFILL GUIDANCE GROUP
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1	19/02/18	Final version for approval by LGG

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1. Introduction

Current guidance and advice concerning geosynthetic interface shear resistance testing is provided within the Industry Code of Practice 'Earthworks in landfill engineering' (Ref. 1) and Environment Agency R&D Report P1-385/TR1 (Ref. 2) together with approved CQA plans. The existing test (BSEN ISO 12957-1 Geosynthetics - Determination of Friction Characteristics - Part 1: Direct shear test) provides an index test method to enable the comparison of different materials against a standard sand. BS 13493 also states that site specific testing should be carried out to establish the friction characteristics between all the materials used.

Appendix A provides guidance on the testing procedure. The proposed testing methodology modifies BSEN ISO 12957-1.

The aim of this code of practice is to provide guidance on the method of testing, testing frequency and the interpretation of the results for design purposes for both geosynthetic/geosynthetic and geosynthetic/soil interfaces.

2. General

Operators must use the services of a suitably experienced civil or geotechnical engineer or an engineering geologist to carry out the liner design.

Your design engineer must revisit the liner Stability Risk Assessment (SRA) using interface shear parameters obtained from laboratory testing on the materials chosen for the contract to demonstrate the robustness of the liner design.

You should discuss your proposals with the Environment Agency before you start any construction works on your landfill.

Geosynthetics supplied to site must have a CE marking.

3. Testing frequency

The minimum frequency of tests should comply with Table 1. Some geomembranes are more variable than others and this should be taken into account when deciding the number of tests to be carried out.

Whilst this does not guarantee the interface shear strength between different products it should reduce the variability. Therefore, the number of tests to be carried out between a geosynthetic and geosynthetic should as a minimum be 1 test for every 10,000m^2 for each interface.

Consideration must also be given to the internal shear strength of geosynthetics that are composite structures, such as GCLs and geodrains.

The testing frequency must reflect the confidence in the interface shear strengths used in the analysis. It is necessary to establish how the design interface shear parameters have been obtained.

A. Are they derived from published sources of generic values for the geosynthetics e.g. EA report TR1 (Ref. 2)?
B. Are they derived from unpublished generic values for the geosynthetics in the designer's database?
C. Are they derived from test values in the particular manufacturer's database for similar geosynthetics?
D. Are they based on test values from previous works on the site for similar geosynthetics from a different manufacturer?
E. Are they based on test values (at least 4 sets) from previous works on the site for the particular geosynthetics from the same manufacturers?

The actual Factor of Safety (FS) chosen will depend upon several factors including consequences of the failure (risks to people, environment, infrastructure, etc.) and the ease of repair (cost, accessibility, availability of materials, timescale, etc.).

The actual FS used in the design must be justified in the SRA. The test frequencies in Table 1 are considered to be a minimum.

Table 1: Risk hierarchy for deciding test frequency

Source of strength data	FS on an interface Analyses based on peak strengths	Number of test sets required per 10,000 m^2 of interface
A or B		4
C or D	FS ≥ 1.75	1
	FS up to 1.75	2
	FS < 1.50	4
E	FS ≥ 1.40	1
	FS < 1.40	2

The FS in Table 1 is the critical Factor of Safety based on worst credible interface shear strength and water/gas pressures as discussed/justified in the SRA.

4. Water pressures (Test/Analysis)

The water pressures in the veneer analysis are commonly expressed as a Parallel Submergence Ratio, PSR where

PSR = perpendicular height of water above the geotextiles / perpendicular height of soil above the geotextiles

= hwater/hsoil = 0 for dry conditions
= 1 for saturated soil

The permeability of the cover soils requires consideration. Where no geosynthetic drainage is used below cohesive cover soils then it is recommended that the minimum PSR considered should be 0.5 (note that higher PSR values may be appropriate in certain cases). Where geosynthetic drainage is used below cohesive cover soils then it is recommended that the minimum PSR considered should be 0.05 (note that higher PSR values may be appropriate in certain cases). However, care must be exercised when using geosynthetic drainage beneath the cover soils in a cap veneer. There is evidence that whilst geosynthetic drainage can reduce the water pressures at the cover soil/drain interface, substantial water pressures can still remain in the cover soils above the geosynthetic drainage depending on the permeability of the cover soils.

PSR can be reduced only if geocomposite drain is providing sufficient flow capacity in long and cross direction. The analysis must ensure that correct platens were used for the standard geocomposite in-plane flow capacity test (BS EN ISO 12958:2010) as this can significantly affect the performance. The analysis should demonstrate that geocomposite will provide sufficient flow capacity to ensure slope stability during construction and for the lifetime of the site. Therefore, adequate long term reduction factors must be considered.

The analysis must consider this water pressure and any gas pressures that exist and consider their effects on possible slip surfaces located in the cover soils above a geosynthetic.

5. Use of the laboratory results in veneer analysis/CQA

In order to assess whether the laboratory results are compliant with the design, the shear strength of each interface, based on the design values derived from the laboratory results, is calculated and compared with the required shear strengths from the design/analysis.

A single laboratory test suite cannot be used without modification to give the characteristic strength and hence the design strength.

Where the resultant factor of safety is less than that considered acceptable within the SRA you should discuss the results with the Environment Agency.

The following are suggested methods of deriving the characteristic strength parameters (BS material design strength parameters) from the laboratory quoted values of interface shear strength parameters.

Test Suites carried out ≤ 2

The Designers Guide to EN1997-1 (Ref. 3) provides guidance in Example 2.1 (page 41) on the selection of characteristic values of parameters from test results of local samples ie:

$$\tan\delta'_k = \tan\delta'_{Lab,\ mean}\,(1 - k_n V_{\tan\delta'})$$

where: $\tan\delta'_k$ = the characteristic value of $\tan\delta'$
$\tan\delta'_{Lab,\ mean}$ = the mean of the laboratory measured values of $\tan\delta'$
$V_{\tan\delta'}$ = the coefficient of variation of the derived values
k_n = a statistical coefficient which depends on the number of test suites carried out.

Similarly:

$$\alpha'_k = \alpha'_{Lab,\ mean}\,(1 - k_n V_{\alpha'})$$

Schneider (Ref. 4) recommends average values for the coefficient of variation of the effective shear strength parameters for SOILS of:

- 0.4 for $V_{c'}$ and 0.1 for $V_{\tan\varphi}'$

Assuming that similar values apply to geosynthetics would give:

- 0.4 for $V_{\alpha'}$ and
- 0.1 for $V_{\tan\delta}'$

Assuming that k_n = 1.2 (for test suites ≤2) then applying the above equations gives:

EC7 $\tan\delta'_k$ = BS material $\tan\delta'_{design} = 0.88(\tan\delta'_{lab\ mean})$ and

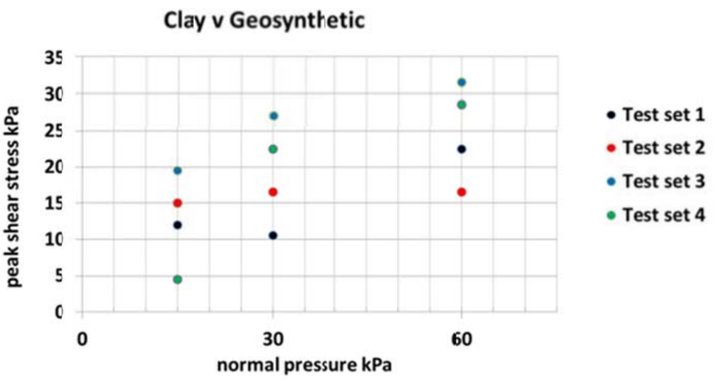
EC7 α'_k = BS material $\alpha'_{design} = 0.52(\alpha'_{lab\ mean})$

These are the values to use in the software to decide whether or not the required shear strength is available on the interface being analysed and hence whether or not the material has met the specification

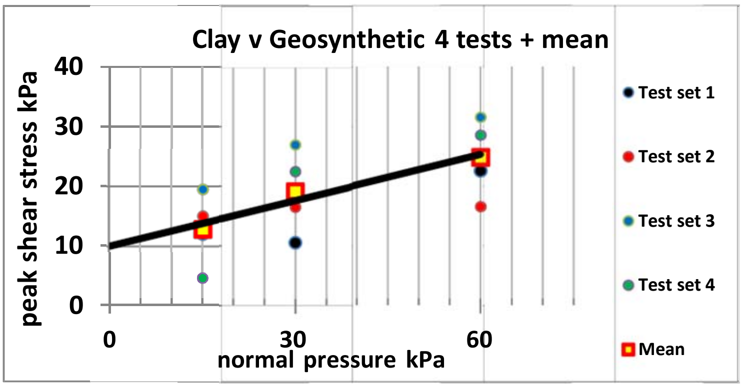
Test Suites carried out > 2

For the method see Reference 4.

The results of shear stress versus normal pressure are plotted. A typical suite of tests could give the following results:

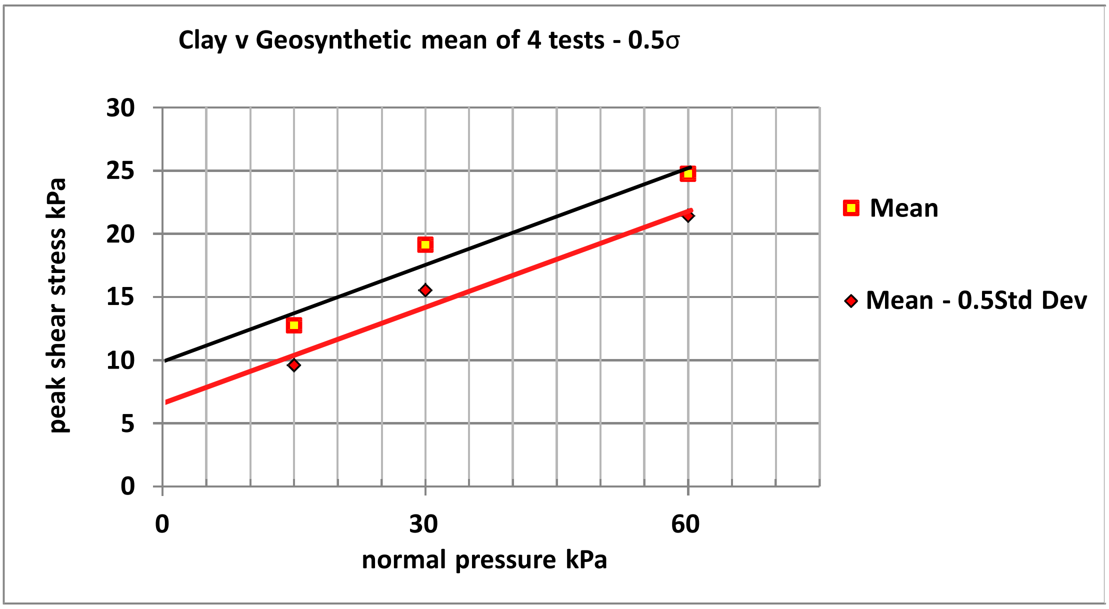


For a number of suites of tests, plot the mean at each normal pressure:



For a number of suites of tests plot the mean at each normal pressure – 0.5σ

Where σ = standard deviation



For the above example the characteristic interface shear parameters are therefore

α_k= 6.6 kPa and δ_k = 14.2^o

12. References

1. Industry Code of Practice, 2012, LFE4/LGG104 -Earthworks in landfill engineering[1]

2. Jones, D.R.V. and Dixon, N. (2003) Stability of Landfill Lining Systems: Environment Agency Report No. 1, Literature Review R&D Technical Report, P1-385/TR1

3. Frank et al, The Designers Guide to EN1997-1. Eurocode 7: Geotechnical Design – General Rules: Thomas Telford, London: 2004: pp41 - 51

4. Schneider H. R. Definition and determination of characteristic soil properties. Proceedings of the 14th International Conference on Soil Mechanics and Geotechnical Engineering, Hamburg, 1997, 4, 2271 – 2274

5. ASTM D5321/D5321M-13 Standard Test Method for Determining the Shear Strength of Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces by Direct Shear

6. BSEN 12957-1 Geosynthetics- Determination of Friction Characteristics - Part 1: Direct shear test.

[1] Note that guidance document LFE4 was produced by the Environment Agency and has now been withdrawn. An Industry Code of Practice (LGG104) to supersede LFE4 is being finalised at the time of writing.