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Standard in-plane flow capacity test for geocomposites and effects on slope stability

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Abstract

This paper explains the importance of using standard BS EN ISO 12958 in-plane flow test and correct testing conditions for all geocomposites and their applications. The standard requires soft platens to be used in contact with the geocomposite to simulate soil backfill and replicate flow capacity reduction due to geotextile intrusion, unless the products are designed to be used against hard structures when the platen specifications can be changed. The test can be carried out using soft or hard platens or one of each and all have their place. However, designers, specifiers and quality engineers need to understand their uses and ensure the products they are specifying provide the correct values for their designed use.

Some geocomposite data sheets state in-plane flow capacity with hard platens. This does not simulate geotextile intrusion and as a result the flow capacities shown are not realistic when a geocomposite is in contact with soil. Using flow values which are unrepresentative of those to be used in site specific situations could result in insufficient drainage capacity on site.

Results from slope stability calculations suggest that this may lead to insufficient drainage capacity and a resulting significant reduction of the factor of safety on landfill slopes. The analysis is significant for designers responsible for ensuring landfill slope stability and the Environment Agency, which should check stability of such slopes.

1. Introduction

Geocomposite drainage products are easily deployed “sheet-drainage-on-a-roll” for rolling out on a smooth surface. They are typically used on large areas and slopes for drainage beneath cover soils to replace thin layers of graded sand or gravel drainage layers. They typically comprise a polymeric drainage core with geotextiles or other geosynthetic sheets bonded on one or both sides.

They are usually covered with soil.

One of the major design aspects of specifying these drainage composites is their in-plane flow characteristics. Especially important is adequate flow capacity within the drainage sheet. If this is inadequate increased head or up-lift pressure can destabilise the covering layer and compromise slope stability. These geocomposites are widely used in landfill sites as part of the cover layers above a low permeability landfill cap, which are typically sloping and covered with restoration soils.

BS EN ISO 12958 is the standard European and international test for in-plane flow capacity for such geocomposite drains to simulate site conditions to provide design engineers with realistic flow capacities that can be used in design. This test determines short-term flow capacity under overburden stress. Different tests, related to creep performance, are used to determine the long-term performance.

The standard BS EN ISO 12958 test requires the use of soft platens to simulate the soil backfill used on site and hard platens are allowed for an interface with hard surfaces. CE markings should quote soft platen flow tests at a nominal 20kPa loading. Soft platens are designed to replicate a site situation where soil applies the confining pressure to the geotextile surface of the geocomposite and consequently the geotextile intrudes into drainage void, resulting in flow capacity reduction (Figure 1). Flow reduction by geotextile intrusion is product specific and can typically range from 1.2 to 100 depending on the make-up of the geocomposite, the nature of the materials adjacent, the loadings and the operating temperature.

The standard requires platens of elastomeric closed cell foam rubber, with a specified compression deflection envelope and specified thicknesses for various geocomposite thickness ranges.

However, some geonot composite data sheets show

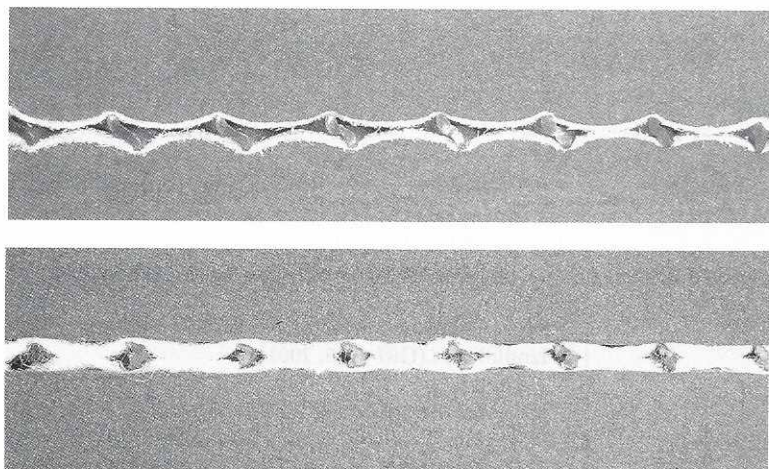


Figure 1 Soft platen test and geotextile intrusion into various types of geonet based geocomposite drainage sheets at 35kPa pressure (a typical landfill cap loading).

in-plane flow capacity tested with hard platens. Hard platens apply the confining pressure to the drainage core only, minimising geotextile intrusion and obtaining sometimes many times higher flow results than can be achieved on site where a geocomposite is backfilled with soil. Hard platen flow capacity is irrelevant for the applications where soil backfill is in contact with geocomposite but is relevant when a geocomposite is installed in contact with hard surface (concrete slab or HDPE geomembrane). Some consider hard-hard tested to be more repeatable, but recent discussions with laboratories suggest this view is not correct.

Design engineers should ensure that flow capacities assumed for their designs and calculations are relevant for their particular applications and check data sheets and test results to ensure they have been correctly specified for the site-specific situation.

2. The test standard: BS EN ISO 12958: 2010 "Geotextiles and geotextile-related product – Determination of water flow capacity in their plane"

The standard describes the Apparatus and Materials:

"The surfaces contacting the specimen shall be closed-cell foam rubber whose properties satisfy the compression-deflection envelope, illustrated in Figure 1 [of the standard] when tested in accordance with ISO 9863-1.

When the geotextile-related products to be tested have been designed to perform their hydraulic functions against rigid boundaries, the foam rubber membranes should not be used, but should be replaced with the adequate boundary, e.g. stiff high density polyethylene liner or concrete panel. Products for such applications can be identified typically by the fact that they have no geotextile layers to prevent soil intrusion, and in fact are not placed directly against a soil boundary.

When foam rubber layers have not been used, the test report shall include the specific boundary used.

3. Typical landfill applications and test boundary conditions

Many landfills require drainage in the capping system above the low permeability cap and below the restoration soils. This is to allow swift drainage rather than saturating the capping soils and decreasing stability on the capping system. This is a concern as most caps have significantly steep slopes. Other landfill uses include incorporating a geocomposite drain as part of a composite leachate drainage layer in the base of a landfill cell, again some parts may be on side slopes and are usually designed in conjunction with a layer of drainage aggregate. Typically the composite is placed above a polymeric geomembrane layer and below the aggregate drainage layer. Other site-specific situations can be envisaged, including use adjacent to geocomposite clay liners (GCL) or below the lining system for ground water drainage.

All geocomposite drains, by their nature, have a series of hard points with voids through which the water travels. The voids are created by the bonded geotextile covering. If the drainage composite is covered with a flexible, compliant material such as soil there will be intrusion by the geotextile straining under the overburden pressure and reduction of the void through which water can flow. The same reduction in void space happens if placed on a GCL when the bentonite within the GCL swells. However, if the geocomposite drainage is placed adjacent to a concrete slab or wall or a semi-rigid polymeric geomembrane liner, significantly less intrusion is likely even under much higher overburden pressures. Each situation is different and site-specific situations should be considered.


Experimental results from physical testing completed by Dickinson, Brachman and Rowe (1995) for base lining applications (ie relatively high stresses) show intrusion of GCL into net composite. Their work shows that GCL/geocomposites interface must be considered as a soft boundary. The amount of GCL intrusion is a function of the confining pressure. Therefore, for the geocomposite that is installed on top of the GCL and backfilled with soil, in-plane flow capacity must be tested as soft/soft (S/S) 



Figure 3 Soft platen test and cusped geocomposite drainage sheets at 35kPa

boundary conditions.

S/S boundary conditions in standard test BS EN ISO 12958 requires soft platens for situations where geocomposite is in contact with soil on one side and GCL on the other or soil on both sides (Figures 1 and 3).

Hard/Hard test (H/H) is valid only if the geocomposite is between hard surfaces such as polymeric geomembranes. Typical example of this would be a leak detection layer between two HDPE geomembranes.

Hard/Soft (H/S) boundary conditions can be carried out if the geocomposite is between the soil backfill and polymeric geomembrane lining. Note that if specifying a H/S test and the material is not uniform side to side, the appropriate instruction should state the appropriate way up for the flow capacity test (Figures 2 and 4).

It is important that flow capacity tests are carried out in both long and cross direction (ie along roll length and across roll length) for steep slope applications as anisotropic flow characteristics are possible, and any choices made followed through to design instructions.

4. Reduction factors in design

In addition to ensuring that the correct short-term flow capacity test result described above is used, which is primarily down to elastic deformation of the adjacent geotextiles by soils and aggregates under overburden pressure, designers must also consider creep under the long-term pressure on both the core and the adjacent geotextiles, and both chemical and biological clogging, and allow for the total performance reduction. The polymeric materials used and the shape and thickness of the core must be considered as well as the environmental aspects of the proposed location, such as the operational temperature range. Also, whether the same intrusion is likely on one or both sides of the geocomposite drain.

However, extensive soft platen test results indicate that reduction factors for geotextile intrusion are dependent on the type of the geocomposite and can be in the range from 1.2 to 30.

Therefore, standard BS EN ISO12958 soft platen test covers the R_{fin} reduction factor indicated by Koerner (2005) but the other reduction factors he describes should also be incorporated in a design flow capacity.

The basic equation for the allowable (design) flow rate should incorporate the following reduction factors (modified from Koerner 2005):

$$q_{\text{allow}} = q_{\text{ult}} \left[\frac{1}{(RF_{\text{cr}} \times RF_{\text{cc}} \times RF_{\text{bc}})} \right]$$

Where:

- q_{allow} = design allowable flow rate
- q_{ult} = ultimate flow rate for short term tests
- RF_{cr} = reduction factor for creep deformation of core &/or adjacent geotextiles (SIM test or 10,000 hour conventional creep test)
- RF_{cc} = reduction factor for chemical clogging/precipitation of the geotextiles or core (product specific)
- RF_{bc} = reduction factor for biological clogging of the geotextile of core

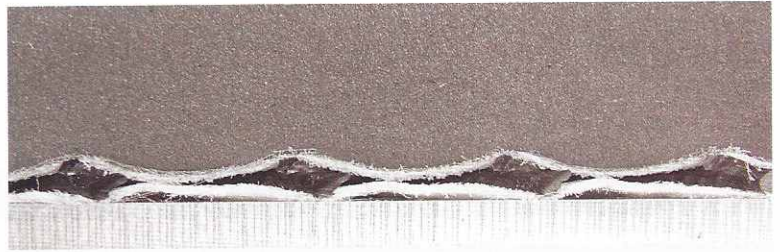


Figure 2 Soft/hard platen test and geotextile intrusion into geonet at 35kPa

Suggested reduction factors for surface water drainage of landfill caps (GRI-GC8, 2001):

$$RF_{\text{cr}} = 1.2-1.4, RF_{\text{cc}} = 1.0-1.2, RF_{\text{bc}} = 1.2-3.5$$

This suggests that an overall long term reduction factor should be between about 2 and 6 to ensure sufficient flow capacity throughout the design life of the landfill cap.

Use of such partial reduction factors complies with the approach followed in Eurocode 7 despite this code not applying to landfill design.

5. Importance of flow capacity for landfill cap slope stability

In evaluating landfill slope stability, all potentially de-stabilising forces must be considered. Great attention to detail is applied to ensure all interface friction angles are sufficient, internal shear strength/bonding/lamination is adequate and construction method is correctly selected. It is strongly recommended that project specific materials are used in all shear box tests in order to simulate site conditions.

Equal attention should be given to the volumes of drainage water, seepage forces and flow capacity of the drainage layer to ensure slope stability. Inadequate flow capacity or laying an anisotropic geocomposite inappropriately could result in soil cover saturation and may affect slope stability.

The high frequency of final cover system slope failures include build-up of seepage forces within the drainage layer and/or cover soils due to inadequate drainage capacity.

Giroud, Bachus and Bonaparte (1995) in their analysis concluded that a landfill slope with insufficient drainage capacity would have reduced factor of safety as water is flowing along the slope within the saturated soil cover: "The analysis shows that the influence of water flow on the stability of a geosynthetic-soil layered system can be very



Figure 4 Soft/hard platen test and cusped geocomposite at 35kPa

significant if the slip surface is above the geomembrane. In this case, the factor of safety of a layered system with water flow can be as low as one half of the factor of safety without water flow”.

Koerner and Soong (1998) indicate that “full submergence of a cover soil will effectively reduce the slope’s factor-of-safety by 50%”.

Therefore, to ensure slope stability it is essential that a geocomposite drain has sufficient flow capacity to prevent soil cover saturation and water flow in the backfill material.

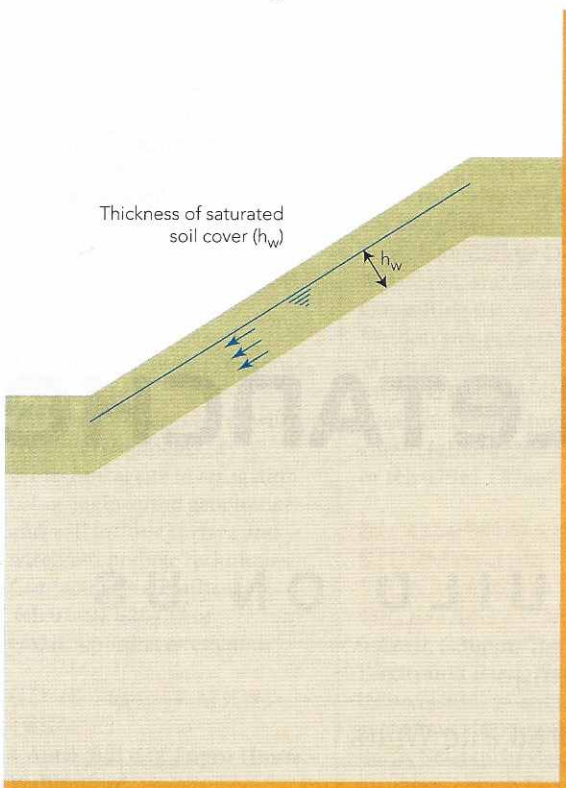


Figure 5 Insufficient drainage capacity resulting in water flow within the soil cover along the slope

In-plane flow capacity standard soft platen test BS EN ISO 12958 is widely used and proven as reliable and repeatable. It provides realistic simulation of cover soil effect on geocomposite flow capacity performance if used correctly. However, designers should be aware that tests carried out with real soil sometimes indicate a further 10-20% reduction in flow capacity (Bamforth 2009).

6. Design example

Consider 1 in 3 landfill cap slope (Figure 5), 30m long with 1m soil cover, unit weight 18kN/m^3 , saturated unit weight 21kN/m^3 , angle of internal friction 30° and cohesion $c = 0$. Interface friction angle between the geocomposite and the overlying soil cover $\delta = 18^\circ$ and apparent adhesion $\alpha = 1\text{kPa}$.

For the geocomposite with a sufficient in-plane flow capacity there is no saturation in the soil cover and the

depth of saturated soil is $h_w = 0$. Resulting slope stability factor of safety is $FS = 1.30$

For the same case where the geocomposite has insufficient flow capacity and thickness of saturated soil cover is $h_w = 0.6\text{m}$, the resulting slope stability factor of safety is $FS = 0.95$.

This clearly demonstrates that misleading in-plane flow capacity of the geocomposite can result in soil cover saturation and slope failure.

7. Summary

To summarise the design approach needed in utilising these useful composites:

- Specify appropriate tests for the site specific situation.
- Check the data sheets for potential products for appropriate flow characteristics under appropriate platen conditions.
- Standard soft platen tests must be used if the drainage composite has adjacent soil, drainage aggregates or GCL
- Published reduction factors for intrusion (RFin) are underestimated, laboratory testing should be performed to evaluate flow performance on a site and drainage composite specific basis
- Hard-hard platen tests are valid only if the geocomposite is between rigid/hard surfaces such as concrete and/or a geomembrane lining;
- Hard-soft platens are required if the geocomposite is between say a geomembrane liner and a soil or aggregate layer.
- All non-compliant (ie non-soft-soft platen tests) test flows should be prominently labeled as such.

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