THE NEED FOR GEOSYNTHETIC STANDARDS AND GENERIC SPECIFICATIONS

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The Specification

What do we mean by a Geosynthetics Specification?

Is it a menu of tests which give a list property values?

Is it a time defined performance requirement?

Do the test methods or performance criteria in the specification meet your understanding of the needs of the particular application or project?

If the specification is lacking in detail or demand it is the responsibility of both the user and the supplier to bring this to the attention of the specifier.

If a “Standard Specification” is being cited does it address and satisfy the functions and requirements that you consider the geosynthetic must fulfil on a particular project?

Standard Specifications are just general guides and often must be modified and made project specific.
Specifications should primarily be based on function, the environment of the application together with regard to the material of manufacture.

In Europe the “Requirement Document” is focuses on the application e.g. Roads, Railways, and Canals etc however within the document the property requirements are functionally lead.

In North America the specifications are functional but strongly linked to the product structure and material content.
The main functions of geosynthetics are:

- Separation
- Filtration
- Reinforcing
- Cushioning
- Barriers and containment

Many applications will require more than one function, e.g. separation and filtration.
An important aspect of any specification is the environment in which the geosynthetic will function.

The environment can be physical, chemical, UV exposure etc.

Additionally the period of time that the particular function must be sustained is critical.
Indicator or identification properties such as mass per unit area or thickness should not be used as a basis of specification or selection.

All properties and characteristics must be given to a confidence level, i.e., the mean values minus a factor of the standard deviation. The use of simple mean value as an indicator of manufactured properties or characteristics should not be permitted.

It is good practice for the issuer of the specification to indicate to the Quality Control Engineer the importance of the various specified property or characteristic.
Geosynthetic standards

There is excellent international and integrated cooperation and consensus on geosynthetic testing standards and procedures exemplifies by the ISO Technical Committee 221.

The host of geosynthetic test methods and assessment procedures for the Engineer to select from. The key to assembling a proficient specification is understanding the function and demands that the geosynthetic has to fulfil

The international nature of geosynthetic commerce has made the propagation of proprietary specification widespread; this has positive and negative aspects. Frequently international companies offer specifications to Engineers which do not mention the product name, while such proprietary specifications are technically competent they are selective in properties and characteristics given as well as being anticompetitive and proscriptive
Geosynthetic Standards World-wide

16-17 November 2006, Boğaziçi Üniversitesi, Istanbul

Reigate, Surrey. United Kingdom
Separation

Separation is the dominant function of geosynthetics when measured in product sold or area covered.

While many of the applications in which geosynthetic separation is required may be low risk, the total economic impact of poor performance is considerable.

There are extensive selections of separation specification available; these vary in applicability and relevance e.g. GRI, IGS, NGS etc.

In many jurisdictions compliance with the “National Specification” is an obligation; nevertheless this adherence should not lead to complacency or lack of rigor in assessing the functional requirements and specification for a particular project.
Separation

The main reason for the failure of geosynthetic separation is puncture and tears together with poor soil retention. Much of the damage to a separator occurs during installation.

Unidirectional tensile strength is a poor indication of separation performance; slow tear propagation tests such as trapezoidal tear are irrelevant and misleading.

Bidirectional puncture, CBR, is a good indicator of separation performance. Dynamic puncture, Drop Cone, is an excellent test for assessing the resistance to installation damage together with tear initiation and tear propagation.

Pore size can be critical in dynamic loading (railways) and with frost susceptible soils. Water flow is seldom a problem in soil aggregate separation.
An irrelevant and misleading geosynthetic test due to the slow speed of tear propagation

TRAPEZOIDAL TEAR
ASTM D4533-91
GAUGE LENGTH 25 mm
SPEED 300mm/min
EN ISO 12236
CBR
(Puncture Test)

EN ISO 13433
Drop Cone Test
Filtration is often the forgotten child of geosynthetics and while not large in commercial importance the consequence of poor or inadequate performance can be catastrophic.

The environment in which the filter will function plays a vital role in the content of the specification. Simple unidirectional low gradient flow in a land drain will allow a much broader specification than would a dynamic reversing flow in a sea wall.

The risk factor and consequence of failure also influence the specification, the hydraulic environment may be similar but few would suggest that the land drain and the toe drain of a dam should be considered with the same diligence.

The CBR and Cone drop are good test to use in specifying the physical properties of a filter geosynthetic.
Filtration

The pore size should generally be defined as $D90$ i.e. the size of opening which is equal to the particle size $d90$ of the granular material that has passed through the geosynthetic.

The pore size should be defined by a wet sieving test EN ISO 12956 other more experimental procedures are under development, bubble point, mercury intrusion but these should only be used as in conjunction with wet sieving.

Dry sieving test should not be used as the values produced have been shown to be inaccurate and misleading.

There are several “rules” and formulae for matching the soil grading to the pore size of the geosynthetic. The accuracy or dependability of these rules can be judged by the considerable range of values that emerge from these recommendations (however most seem to work).
**Filtration**

In general for unidirectional flow keep the O90 below the d90 and above the d50 of the soil to be filtered. Due to the likely establishment of a filter zone in the soil adjacent to the geosynthetic the tolerance on the compatibility of O90 to d90 is large.

For reversing and turbulent flow keep the O90 below the d60 and above the d30 of the soil to be filtered, however the tolerance between the pore size of the geosynthetic and the soil is small.

If the project is large or of a critical nature or if the soil has fine and uniformly graded (dredged soil) then a reversing flow test type German Federal Waterway Engineering and Research Institute (BAW) Mechanical filtration stability for very fine grained soils (reversing turbulent flow method) should be carried out.
EN ISO 12956 (WET SIEVING)

- WATER SUPPLY
- SPRAY NOZZLE
- CLAMPING DEVICE
- GRANULAR MATERIAL
- SPECIMEN
- SUPPORT GRID
- PAN
- CONNECTING TUBE
- FILTER PAPER
- COLLECTING DEVICE
- AMPLITUDE REGULATOR

16-17 November 2006, Boğaziçi Üniversitesi, Istanbul
Filtration

The water flow through filter geosynthetics is generally more than sufficient however the conventional water flow test EN ISO 11058 does tend to overestimate the water flow particularly with needle punched structures.
A more realistic appraisal of the water flow can be obtained by testing to the draft ISO Determination of water permeability normal to their plane under load. This test procedure tests the water flow to confining pressure of 200 kPa which can be of interest in dam filtration.

Geosynthetic filters can be clogged by bacterial growth, the inclusion of graded granular layers in conjunction with the geosynthetic can mitigate this problem however if significant bacterial or mineral clogging is anticipated than the use of a geosynthetic filter may be inappropriate.
EN ISO 11058
WATER FLOW

INFLOW OF WATER

WATER HEAD

OUTFLOW OF WATER TO BE COLLECTED AND TIMED

SPECIMEN
Draft ISO WI1026A Determination of water permeability normal to their plane under load.

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Drainage geosynthetics in the form of filter-core composites are being increasingly used. These are being utilized to evacuate both fluids and gasses.

The specification of the cover filter is addressed previously however the peel strength of this filter and the aqueous stability of the filter adhesion to the core should be tested by pre-soaking prior to the peel test.

The primary test for the drainage is the EN ISO 12958 - Determination of water flow capacity in their plane however this test must be done in conjunction with EN13432 - Determination of compressive creep properties, this test procedure must be carried out in the compression and shear mode.

When specifying the testing parameters for EN ISO 12958 it is important to select a hydraulic gradient appropriate to the actual application.
EN ISO 12958 IN PLANE WATER FLOW (TRANSMISSIVITY)

- PNEUMATIC RAM
- LOAD
- PRESSURE GAUGE
- LOADING PLATEN
- WATER RESERVOIR
- WATER SUPPLY
- OVERFLOWS AT 1.0 & 0.1
- HYDRAULIC GRADIENTS
- BASE
- POSSIBLE FOAM RUBBER CONTACT
- COLLECTING DEVICE
- WATER HEAD
- SPECIMEN

0.3m min.
100mm max.

WATER HEAD

POSSIBLE FOAM RUBBER CONTACT

COLLECTING DEVICE
EN ISO 13432
DETERMINATION OF COMPRESSIVE CREEP PROPERTIES

APPLIED NORMAL LOAD

SPECIMEN

WATER (IF REQUIRED)

MEASURING DEVICES

ADJUSTABLE FULCRUM

SHEAR LOAD
Reinforcing specifications are often the most markedly proprietary and are dominated by unidirectional strength.

The specification requirements of a reinforcing geosynthetic can be divided into Serviceability and Limit State condition.

**Serviceability**

The “in use” condition of most reinforcing geosynthetics do not exceed 3% elongation. The unidirectional tensile strength at 2.5% is therefore important and this must be determined without pretension or “capstan massage”.

The frictional properties according to EN ISO 12957-1 should be assessed with representative aggregate as well as the geosynthetic face to geosynthetic face friction.
EN ISO 10319
WIDE WIDTH TENSILE TEST
ISO 12957-1 DETERMINATION OF FRICTION CHARACTERISTICS – PART 1: DIRECT SHEAR TEST
Measurement of Peak and Residual Shear Strength

After the peak strength is achieved there is a rapid reduction in shear strength to a residual level.

Displacements (mm)

Shear Stress (kPa)

Peak shear strength

Residual (or large strain) shear strength

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The specification for a geosynthetic reinforcement should ask for the reduction factors used.

- Installation damage
- Creep deformation
- Chemical degradation
- Biological degradation

If seams or connections are to be employed then the allowable strength shall per unit width or connection point shall be given.

The specification should give the required working load at a specified time, (i.e. 75kN at 100 years)

In addition the specification should require the stress rupture plot for the specified lifetime of the structure on a linear strength to log time base.
DD ENV ISO 10722-1  Procedure for simulating damage during installation
Part 1: Installation in granular materials

Aggregate loose in upper box
300 x 300 mm
2 part steel box
H = 2 x 75 mm

Geosynthetic specimen b = 250 mm

Applied load
Cyclic loading
5 kPa TO 900 kPa @ 1 Hz

Loading plate 100 x 200 mm

Aggregate compacted in lower box

Geosynthetic surplus rolled outside box

Rigid base support

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Accelerated creep testing

SIM
Stepped Isothermal Method

Rigid support frame
Spherical seating
Heating chamber
Specimen grips
Specimen
Specimen grips
Adjustable fulcrum to allow the load lever to be kept constant during the test

Load support lever
Spherical seating
Load

Temperature °C

Time hours

16 Hours
104
6

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Relationship between creep, creep rupture and isochronous stress-strain

\[ t = \text{Time} \]
\[ \varepsilon = \text{Strain} \]
\[ \sigma = \text{Stress} \]

Isochronous stress-strain

Creep rupture
Creep-rupture diagram including SIM tests

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Reinforcing - Limit State

A realistic factor of safety may be 1.2 but only if the available peak strength resistance from the geosynthetic is compatible with the peak soil resistance.

 Isochronous creep curves

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Soil and particular compacted granular soil has its peak shear strength at between 3% and 5% and it is important to call for the strength at 2.5% particularly for high strength geosynthetics as this can expose inadequate manufacturing expertise.

**Graph:**
- **Load** vs. **Extension**
- **A** and **B** points on the graph indicate the load-extension characteristics with specific emphasis on the 2.5% extension for high strength geosynthetics.
In almost all reinforcing geosynthetic applications, the reinforcement works in conjunction with the soil.

The strength at 6% deformation is a realistic limit state strength for a reinforcing geosynthetic as the soil shear resistance is reducing rapidly beyond the peak shear strength deformation.

If the ultimate strength of the geotextile is to be utilized in the analysis then the residual shear strength of the soil should be used and defined at the geosynthetics ultimate strength deformation.
Cushioning

The use of a cushion layer to protect a geosynthetic barrier is common in landfill and other barrier applications.
Cushioning

Specifications based on weight per unit area should be rejected. The physical properties are well covered by CBR and Drop Cone. The use of directional test such as Grab Tensile or slow tear prorogation test such Trapezoidal Tear are poor indicators of performance and should be deprecated and never used.

In isolation pin and pyramid puncture test (EN 14574) do not mirror the reality of protection efficiency and so inadequate cushion geosynthetic can exhibit excellent test values with these tests.
Cushioning

The cushioning geosynthetic specification should require the EN 13719 - Determination of long-term protection efficiency. This test allows the interaction of the geosynthetic barrier, the geosynthetic cushion and the cover aggregate.

The advantage with this test is that realistic loads and fill can be applied over time and that the deformations can be captured.
Cushioning

**EN 13719 The % strain across the thee worst indentations**

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**Barriers**

*Polymeric barriers*

Geosynthetic barriers are often specified by polymer rather than properties.

The prime property of any barrier is its resistance to liquid and gas; surprisingly these two characteristics are rarely specified.

**EN14150 - Determination of permeability to liquids** allows a threshold measurement of water flow accurately down to $10^{-6}$ m$^3$/m$^2$/day. This test is now a requirement in Europe.
Gas permeability of polymers
The ASTM D 1434 is widely used as the test procedure for the gas permeability of geosynthetics, however the ASTM F1769 - Measurement of Diffusivity, Solubility and Permeability of Organic Vapour Barriers using Flame Ionization Detector is a more meaningful test and it is hoped that ASTM F1769 will be the required test for gas transmission in both the USA and Europe the near future.

Gas permeability of GCLs
The gas permeability of geosynthetic clay liners-barriers (GCL) is a critical issue. The European Geosynthetics Committee CEN TC189 has developed a test procedure which is provisionally in use and is in the process of being voted into a mandatory requirement in Europe.

Effect of wetting and drying on the gas permeability of a GCL

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CEN TC189 - Work Item 97 - Geosynthetic clay barriers – Determination of the permeability to gases

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<table>
<thead>
<tr>
<th>Test Method</th>
<th>Comment</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>Too much emphasis is placed on this property; it is an identifier not a hydraulic property</td>
<td>EN 964-1 (GCL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 1849-2 (POLYMER))</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 1849-1 (BITUMINOUS))</td>
</tr>
<tr>
<td>Density</td>
<td>This is an identifier, in the extreme it will indicate physical characteristics but has little to do with hydraulic properties</td>
<td>ASTM D1505</td>
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<td></td>
<td></td>
<td>ASTM D792</td>
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<tr>
<td>Tensile Properties</td>
<td>Required properties</td>
<td>ISO 527</td>
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<tr>
<td>- yield strength</td>
<td></td>
<td>ASTM D6693</td>
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<tr>
<td>- yield elongation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(both directions)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water permeability</td>
<td>Essential requirement</td>
<td>EN 14150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM D5887 Index flux</td>
</tr>
<tr>
<td>Gas permeability</td>
<td>Essential requirement</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear Resistance</td>
<td>Done more out of tradition than meaning, does not replicate site damage</td>
<td>ISO 34 (POLYMER)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM D1004 (POLYMER)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN 12310-1 (BITUMINOUS)</td>
</tr>
<tr>
<td>Puncture Resistance</td>
<td>This could be a meaningful test if modified but in its present slow strain mode it is worthless</td>
<td>ASTM D 4833</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EN ISO 12236</td>
</tr>
<tr>
<td>Protection efficiency</td>
<td>Important test done in conjunction with cushion geosynthetic</td>
<td>EN 13719</td>
</tr>
<tr>
<td>Stress Crack Resistance</td>
<td>This is necessary but only has importance for HDPE</td>
<td>EN 14576</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASTM D5397</td>
</tr>
<tr>
<td>Carbon Black Content</td>
<td>A money maker for laboratories</td>
<td>ASTM D1603</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>An even bigger money maker for laboratories</td>
<td>ASTM D5596</td>
</tr>
<tr>
<td>Oven Aging</td>
<td>Good simple test</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV Resistance</td>
<td>A meaningful test if carried out correctly and will soon show if the carbon content or the UV stabilizer is deficient</td>
<td>EN 12224</td>
</tr>
<tr>
<td>Chemical degradation</td>
<td>Important test</td>
<td>EN 14414 (all)</td>
</tr>
<tr>
<td>Biological degradation</td>
<td>Often asked for, important for laboratory’s profitability, never known a geosynthetic to fail the test in 30 years of practice</td>
<td>EN 12225</td>
</tr>
</tbody>
</table>
When all these barrier properties are specified, tested and approved it is the seams that hold the key to the success of the functioning of the barrier. **SEAMS SEAMS SEAMS**

Seams are fabricated in the field, subject to poor support, hot and cold weather, rain and a large amount of human error.

Require that barrier is produced in the factory with ISO 9000 with CE approval and accreditation and demand to see factory control records (FPC) for the delivered product.

The key to a successful geosynthetic barrier specification and installation is correct and diligent “Construction Quality Assurance” (CQA) on site.
Conclusions

A meaningful and precise geosynthetic specification will depend on the geosynthetic’s function being well defined.

There are dozens of test procedures to describe all kinds of geosynthetic properties and characteristics, choose carefully and prioritise the key functional properties.

Do not ask for a property that has no standard means of definition, we would all like to know the resilient modulus at 1% elongation after 10E6 cyclical loadings but there is no standard test.

Use only control and testing laboratories that have full accreditation for all tests and that have an established ethical reputation.
Conclusions – continued

Take advice from all quarters but remember sales people are there to sell, ask for advice but get the name of the technical manager, if they do not have one look elsewhere.

Specification are a developing, products change, new products arrive. Do not make the specification too ridged and be prepared to revise in the light of experience and knowledge, Establish and fixed specifications make the specifier and the supplier lazy and inattentive.

THANK YOU FOR LISTENING