Geosynthetics Asia'97, 26–29 November, Bangalore, India

FILTRATION AND DRAINAGE USING GEOTEXTILES

J.C. Curtis

Polyfelt Geosynthetics (UK) Ltd, Unit C2, Haybrook Industrial Estate, Halesfield 9, Telford, Shropshire TF1 4XY, UK

Introduction

The use of geotextiles has grown rapidly in the course of the past thirty five years, and their continuing development and refinement has resulted in the use of geosynthetics as a generic term. Correctly designed geotextile filters are often used as a replacement for graded granular filters, or as an aid to the performance of such systems, whilst geocomposite drains incorporating a geotextile and a drainage core are used in place of granular drains.

Filter Design Methods

The requirements for a geotextile filter are essentially the same as those for a graded granular filter, in so far as the pore size of the filter should be small enough to prevent an unacceptable level of migration of the soil particles, yet not so small as to impede the flow of liquid from the soil.
Desgn methods for geotextile filters fall into one of two broad categories, the first of which considers the pore sizes of the geotextile and the particle size distribution of the soil. The second involves laboratory testing of soil/geotextile systems either from the project site or using typical soils. Each of these tests monitor how the system flow rate changes with time, which allows an assessment of the geotextile from the viewpoint of retention and permeability.

Geocomposite Drain Design Methods

The design of the core of a geocomposite drain must satisfy four main criteria:

- The core must resist the applied loads, both normal and shear;
- Under sustained load the core must not reduce significantly in thickness;
- The core must allow the expected water flow to reach the discharge point without a build up of fluid in the core.
- The core must support the geotextile filter.

Conclusion

Geotextiles for use as filters or drains must be correctly designed, and in demanding application areas designs based on index test properties may not be appropriate. By definition, index testing does not account for specific site parameters and consequently in critical areas more rigorous methods are required.

Geotextiles manufactured from polymers were first used in erosion control systems as an alternative to graded granular filters in the early 1960's, and were originally described as filter fabrics. At this time, most products were of woven monofilaments and were utilised in coastal defence applications. Later that decade, non-wovens being produced in France and in the United Kingdom were being used, primarily in separation and reinforcement. It was soon realised that these thick felts could also transmit water within the plane, and therefore act as a drain within the soil mass to dissipate pore water pressures.

Filtration

For a geotextile to function successfully as a filter, it must provide minimum performance criteria.(Tab.1) (1)

	Mechanical Filter Stability	**Hydraulic Filter Stability**	**Long-term Performance**
Permanent Filter Function	• Effective geo-textile opening size D_W • Geotextile Thickness t_g	• Geotextile permeability **k**	• Chemical properties of water and soil • Chemical Stability • Decay Resistance
Temporary Filter Function	• D_W • t_g	• **k**	-

Tab.1 Parameters of influence for 'Filtration'

Filtration can be defined as 'The retention of soil particles whilst allowing free water flow normal to the geotextile plane'. Therefore the geotextile must exhibit mechanical filter stability by preventing the washing out of fine particles by meeting filter criteria for effective opening size, D_W. Similarly, the geotextile must have hydraulic filter stability by providing pressure-free water flow by meeting filter criteria for required permeability k. To provide long term performance the geotextile must not clog, and it must be resistant to chemical and biological decay.

The flow of groundwater through soils is usually low velocity laminar flow, and according to Darcy's Law, the flow velocity of water in the ground is proportional to the hydraulic gradient:(Fig.1)

$$v = k.i,$$

where v = flow velocity
k = soil permeability
i = hydraulic gradient

Fig.1 Darcy's Law

The flow of water across the plane of a geotextile is determined by the head loss between the upstream and downstream faces of the fabric. If the difference in head is termed Δh, and the thickness of the geotextile is t_g, then the hydraulic gradient across the fabric can be quantified as $i = \Delta h / t_g$. Given that the flow is laminar then Darcy's Law applies and the permeability coefficient k_g of the geotextile can be calculated. However the compressibility of the geotextile under load must also be considered, so the permittivity, defined as the coefficient of permeability and geotextile thickness, must be considered.(Fig.2)

$$\Psi = k_g/t_g$$

where Ψ = permittivity
k_g = geotextile permeability
t_g = geotextile thickness

Fig.2 Permittivity

Test Methods - Index Tests

Index tests are comparitively simple tests devised to determine the performance of a geotextile under artificial environments, and they do not consider any interaction between the geotextile and the soil. An index test therefore is used to set minimum performance criteria, and provided that they are measured to the same or equivalent test standards then the performance of one geotextile can be compared with another. The problem is that there are innumerable specifications for index tests throughout the world, mostly based on soil mechanics tests or those developed for the textile or plastics industries. Even two of the best known standards organisations, the American Society for Testing and Materials (ASTM),(2) and the British Standards Institution (BSI) (3) cannot agree, for example, on a finite test method to determine the Apparent Opening Size (AOS), O_{95} of a geotextile. Whilst the general test descriptions are similar, procedures are not.(Tab.2)

	BS6906 1989, Part 2	ASTM-D4751 1995
Sieve Size Diameter (mm)	300	200
No. Samples Tested	3	5
Method	Sieve LARGEST ballotini first	Sieve SMALLEST ballotini first
Static Elimination	No	Yes

Tab.2 Comparison of Test Methods

Efforts are being made to progress international standards through the International Organisation for Standardisation (ISO), and whilst the differences are often matters of detail and emphasis rather than principle, the design engineer must be aware of them. (4)

Test Methods - Performance Tests

To bridge the gap between laboratory based index testing and site practice, performance tests have been devised to determine how geotextiles perform in service. Site trials are expensive however, and unless the project is major in terms of cost or the consequences of failure, site specific performance tests would not be carried out. Instead, a range of standard soils which cover those typically found in practice are used, and the conditions imposed in these tests simulate as closely as possible the site conditions.
The most direct approach is to take a sample of the soil at the site and place it in contact with the geotextile under consideration.(5) The Long Term Flow Test (6) evaluates the potential for clogging of a geotextile over a long period of time, set as 1000 hours. With a reported transition time of approximately 10 hours for granular

soils and 200 hours for fine-grained soils, the soil/fabric system will begin its simulated behaviour pattern. When plotting the results, if the curve returns to zero after the transition time, then the fabric is compatible with the soil. If the curve continues to be negative clogging is indicated, whilst positive gradients indicate upstream piping.(Fig. 3)

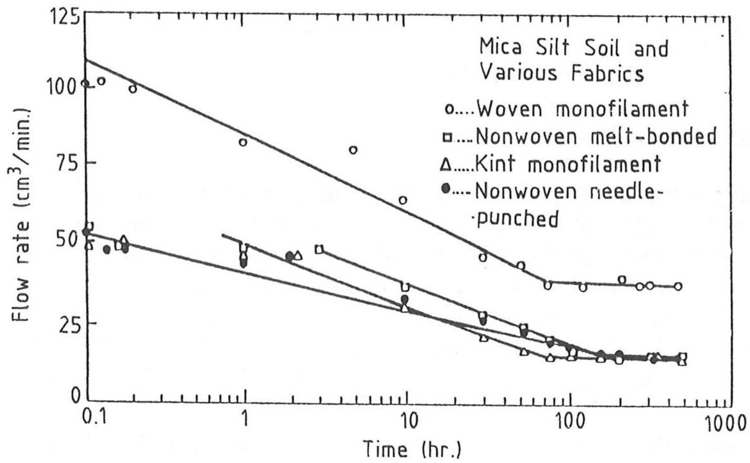

Fig.3 Long Term Flow Tests on soil-fabric systems, (after Koerner & Ko)

A test which can be performed in 24 hours is the Gradient Ratio Test (7) first developed by the US Army Corps of Engineers,(8), which determines the hydraulic compatibility of a soil/fabric system. The test set-up is similar to the Long Term Flow Test, but instead of flow rates, the hydraulic head at various positions in the column are measured. As fine soil particles adjacent to the geotextile are trapped and clog the surface, the gradient ratio increases. The Corps of Engineers suggest that gradient ratios more than 3 show unacceptable geotextiles for the type of soil under test, based upon extreme gap-graded soils. (Fig.4)

An evaluation of the test was reported (9) using very severe test conditions with high hydraulic gradients and cohesionless, gap-graded soils. Critically, the amount of silt passing through the high POA (percent open area) wovens showing such low gradient ratio volumes was not reported

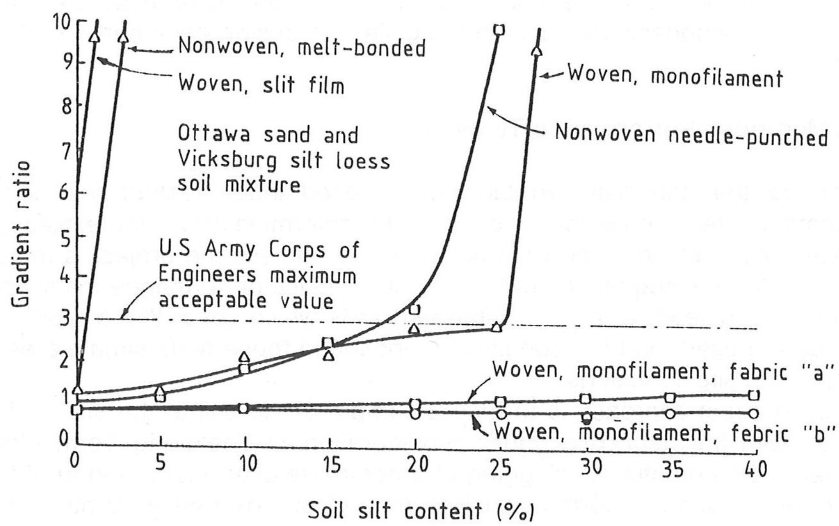

Fig.4 Gradient Ratio test data to indicate fabric clogging potential (after Haliburton & Wood)

Drainage

Drainage as related to geotextiles can be defined as 'Free liquid flow in the plane of the geotextile' Clearly, the in-plane flow of a geotextile may be subject to compressive stress under load, so the transmissivity is calculated as:

$$\theta = k_p\, t,$$

where θ = the transmissivity
k_p = the in-plane permeability coefficient
t = the thickness at a specified normal pressure

Fig. 5 Transmissivity (5)

To function successfully as a drain, the geotextile must maintain adequate thickness during increased overburden pressure thereby maintaining water flow in its plane with minimum loss of pressure. It must resist clogging and be both chemically and biologically resistant.

	Mechanical	**Hydraulic**	**Long-term performance**
Permanent Drainage Function	• Influence of normal overburden pressure σ_n	• Permeability k • Thickness t_g • EOS D_w	• Chemical properties of water and soil • Chemical and biological resistance
Temporary Drainage Function	• σ_n	• k • t_g • D_w	-

Tab.3 Parameters of influence for 'Drainage' (1)

Test Methods - Drainage

Testing for hydraulic transmissivity under compressive stress to BS6906: Part 7: 1990,(2) and to ASTM-D 4716: 1987, (3) are similar, where the geotextile to be sampled is placed in the apparatus over the appropriate substrate or base. The top plate is then placed on the geotextile and a seating stress applied. Water is then introduced and the appropriate hydraulic gradient and test pressure applied. (Fig 6) The hydraulic transmissivity is calculated.(Fig.7)

Geocomposite Drains

Geocomposite drains are described as 'A combination of a geotextile filter and a core through which a fluid can be transmitted to a discharge point'. (10) Generally the cores are constructed from nets, random fibres, cuspated, pillar, or corrugated structures. (Tab.4)

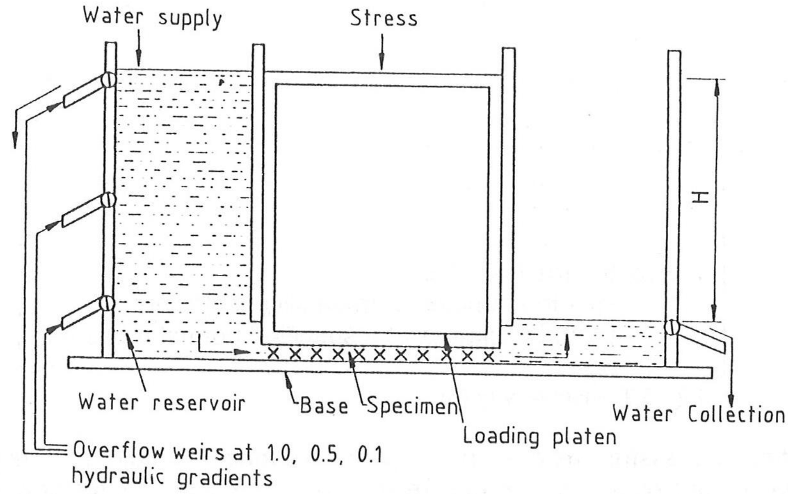

Fig.6 Apparatus for Determination of in-plane water flow (acc. BS6906: Part 7: 1990)

$$\theta = (QL) / (WH),$$

where θ = hydraulic transmissivity (m^2/sec)
Q = average quantity of fluid discharged per unit time (m^3/s)
L = length of specimen
W = width of specimen (m)
H = difference of total head across specimen (m)

Fig. 7 Calculation of Hydraulic Transmissivity (acc. BS6906: 1990, ASTM D 4719:1987)

Core Type	Polymer Type	Characteristics
Two-strand net	Polypropylene PP Polyethylene PE	• Medium/Low transmissivity • Medium resistance to compressive creep
Random Fibres	Polyamide PE	• Medium/Low transmissivity • Best at low/medium lateral pressures • Subject to creep
Cuspated	PP	• High transmissivity • Can resist high lateral pressure • Subject to collapse under load • Subject to collapse due to progressive creep • Shear loads can affect behaviour
Pillar	PP	• High transmissivity • Subject to collapse, especially under shear load • Subject to collapse due to progressive creep
Corrugated	PP PE	• Low transmissivity • Resist high lateral pressure • Thin for use as band drains

Tab.4 Geocomposite cores

With regard to highway edge drains, Clause 514 of the Specification for Highway Works (11) includes not only minimum requirements for the geotextile filter, (Tab.5) core thickness and in-plane flow, but also a method to determine the contact area of the drainage core.

Index Property	Specified Limit	Test Method
Tensile Strength/Strain	min. 5kN/m / min 10%	BS 6906 Part 1
Puncture Resistance	min. 1200N	BS 6906 Part 4
Tear Resistance	min. 200N	ASTM D 4533-85
Pore Size O_{90}	Site Specific by Design*	BS 6906 Part 2
Water flow	Site Specific by Design*	BS 6906 Part 3
Breakthrough Head	max. 50mm	BS 6906 Part 3

Tab. 5 Geotextile requirements for Fin Drains, (acc SHW Cl.514.4)

The Pore Size for the geotextile should be selected using filtration criteria to be compatible with the adjacent soil or construction layer in order to prevent the occurance of piping. (Tab.6)

Uniformity Coefficient of d_{60} / d_{10} soil (Cu)	Woven & Heat bonded Geotextiles	Needle punched Geotextiles
1 to 5	$O_{90} / d_{50} = 1$, to $O_{90} / d_{50} = 3$	$O_{90} / d_{50} = 4$, to $O_{90} / d_{50} = 6$
> 5	$O_{90} / d_{90} < 1$, or $O_{90} / d_{50} < 3$	$O_{90} / d_{90} < 1.8$, or $O_{90} / d_{50} < 6$

Tab.6 Pore size (AOS, O_{90}) criteria for Fin Drains, (acc. SHW CL.NG514.2)

The in-plane flow capacity of the fin drain should be specified by the designer, allowing for infiltration through the pavement and any other source of ground water ingress. As fin drains are normally laid at a constant depth below the carriageway its gradient will follow that of the road.

Conclusion

It is clear that technical innovation from the manufacturers of geosynthetic products will continue as new materials and manufacturing techniques are effected. Their properties, method of manufacture, and how the polymers used can affect their performance must be understood before design is undertaken. Whilst Index Tests offer a method of comparing geosynthetic products, it is vital to ensure that comparisons are made only using the same test standards. Designs using site specific Performance Tests should be carried out where appropriate.

References

(1) Geotextiles Design and Practice, Chemie-Linz AG, 1986.
(2) ASTM Standards on Geosynthetics, 4th Edition, 1995.
(3) British Standard Methods of Test for Geotextiles, BS6906, 1987 - 1991.
(4) Ingold, TS, Geotextiles and Geomembranes Manual, 1st Edition, 1994.
(5) Koerner, RM, Designing with Geosynthetics, 2nd Edition, 1990.
(6) Koerner, RM, and Ko, FK, 'Laboratory Studies on Long Term Drainage Capability of Geotextiles', Proc. 2nd Int. Conf. Geotextiles, Las Vegas, 1982.
(7) Measuring the Soil/Geotextile System Clogging Potential by the Gradient Ratio, ASTM D 5101-90.
(8) US Army Corps of Engineers, Test CW-02215, 1977.
(9) Haliburton, TA, and Wood, PD, 'Evaluation of US Army Corps of Engineers Gradient Ratio Test for Geotextile Performance', Proc. 2nd Int. Conf. Geotextiles, Las Vegas, 1982.
(10) Corbet, SP, 'Geotextiles in Filtration & Drainage', Proc. Geofad '92, Cambridge UK.
(11) Specification for Highway Works, Vol.1, 1991, HMSO.