

Designing by Function

Overview of Functions

- Geosynthetics applications can be classified according to *primary* functions
- However, it is important to note that geosynthetics may also perform one or more *secondary* functions

Function vs. Geosynthetic Type

Type of Geosynthetic	Separation	Reinforcement	Filtration	Drainage	Containment
geotextile	√	√	√	√	
geogrid		√			
geonet				√	
geomembrane					√
geosynthetic clay liner					√
geopipe				√	
geofoam	√				
geocomposite	√	√	√	√	√

Design Methods

- (a) "Cost"-based on experience/availability
- (b) "Specification" – for common applications
- (c) "Function" – for specialty, critical and/or permanent applications

Design Methods

Design by experience:

- **Based on the use of the manufacturer's literature and the designer experience & familiarity with geosynthetic products**
- **Method is technically weak and is outmoded by current standard of practice**

Design Methods

Design by specifications:

- **Often consists in selecting products for common application areas, taking as a basis minimum or maximum specified property values**
- **Very common when dealing with public agencies i.e., RTA, Vicroads, etc.**

Design Methods

Design by function:

- **Required for application not covered by specs or when large damage would result in the event of a failure**
- **It consists of assessing the primary function that the geosynthetic will serve and then calculating the required numerical value of a particular property for that function. Dividing this value into the candidate geosynthetic allowable property value gives a safety factor**

Design by Function Concept

$$FS = \frac{\text{Allowable (test) Property}}{\text{Required (design) Property}}$$

- **Test methods are from AS, ASTM, CEN or ISO**
- **Design models are from literature**
- **Factor of safety is site specific**

Testing Issues

- **ASTM Committee D-35 (methods, practices and guides)**
- **Subcommittees (TG's)**
 - Mechanical
 - Hydraulics
 - Endurance
 - Geomembranes
 - Geosynthetic Clay Liners
- **ISO is very active**
- **Topics are the same, but ISO & ASTM differ somewhat in details and procedures**
- **Aussie Standards are also available**

Reduction Factors

- **Concept - modify an index test value to a site-specific performance value**

where

$$\text{Property}_{(\text{allow})} = \text{Property}_{(\text{test})} \left(\frac{1}{\text{RF}_1 \times \text{RF}_2 \times \dots} \right)$$

RF_i = those details not included in test

- **Currently used for reinforcement and flow related problems**
- **Not currently used on barrier problems**

Design Models

- Utilize geotechnical, hydraulic, environmental engineering concepts
- FEM
- Judgment (i.e., empiricism) still required, but models are improving rapidly

Recommended FS-values for cover systems

Note: Site specific conditions take precedent, regulatory issues are equally important

Type of Waste → ↓Ranking	Hazardous waste	Non - hazardous waste	Abandoned dumps	Waste piles and leach pads
Low	1.5	1.3	1.4	1.5
Moderate	1.7	1.4	1.5	1.6
High	2.0	1.5	1.6	1.7

*other problems will have other defined FS-values

Comments on Safety Factors

		Time	
		Temporary	Permanent
S e v e r i t y	Non-critical	Moderate	High
	Critical	High	Very high

Design by Function Concept

Evaluate criticality & severity of the application

Determine function(s) of the geosynthetic

Estimate or determine the required property of the material

Calculate the factor of safety

Determine if FS is significantly high for the site specific situation

Prepare specs & construction doc.

Observe constr. & post-constr. Performance

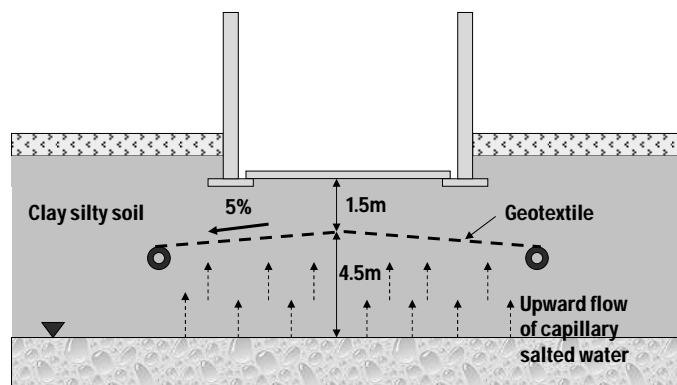
Designing by Function: Selected examples

Capillary migration breaks

- **The upward movement of water un fine grained soils has been known to present problems in arid and semi arid regions (also in cold regions)**
- **As groundwater rises it brings dissolved salts with it. As this salt-ladened water comes near the surface, it kills all vegetation. Equally severe is the salt attacking building foundations**

Example 1

Given a storage building that is to be founded on the site illustrated below, with a capillary break beneath the building's foundation, a geotextile is being considered as a solution. Will a 700 g/m² nonwoven geotextile having an allowable transmissivity $\theta_{\text{allow}} = 0.0007 \text{ m}^2/\text{min}$ at 25 kPa normal stress be adequate using a global FS=3?



Step 1: Determine flow rate of upward water migration (function of soil's permeability), $q = 2.7 \cdot 10^{-5} \text{ m}^3/\text{min}$

Step 2: Calculate the gradient of flow in the geotextile.
5% slope = 0.05

Step 3: Calculate the required transmissivity, θ_{reqd}

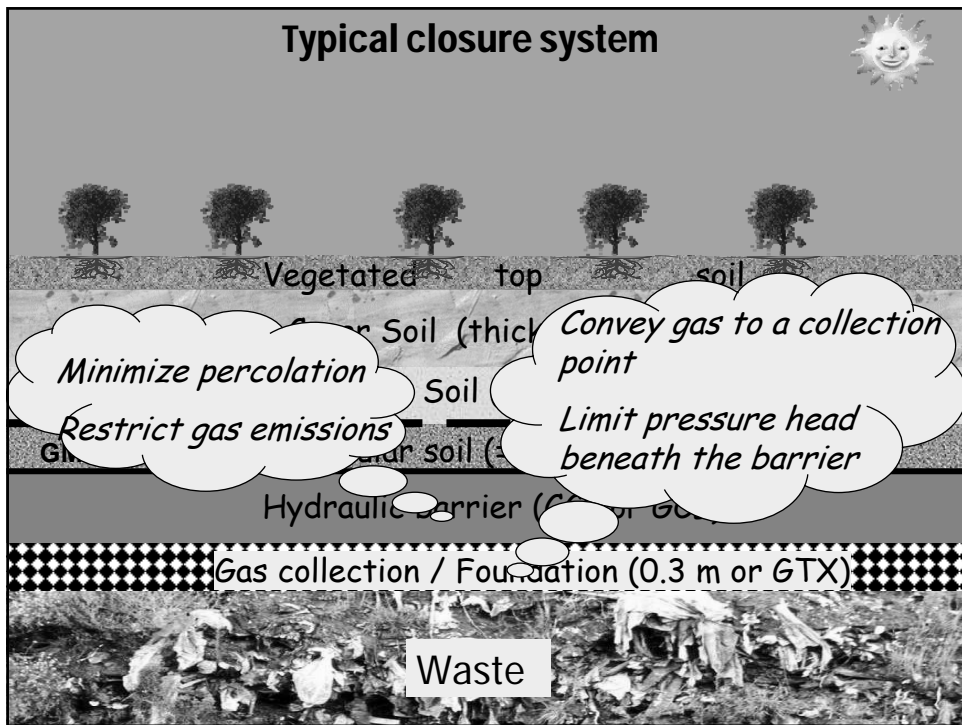
$$q = k i A = k i (t \times W) = k t (i \times W)$$

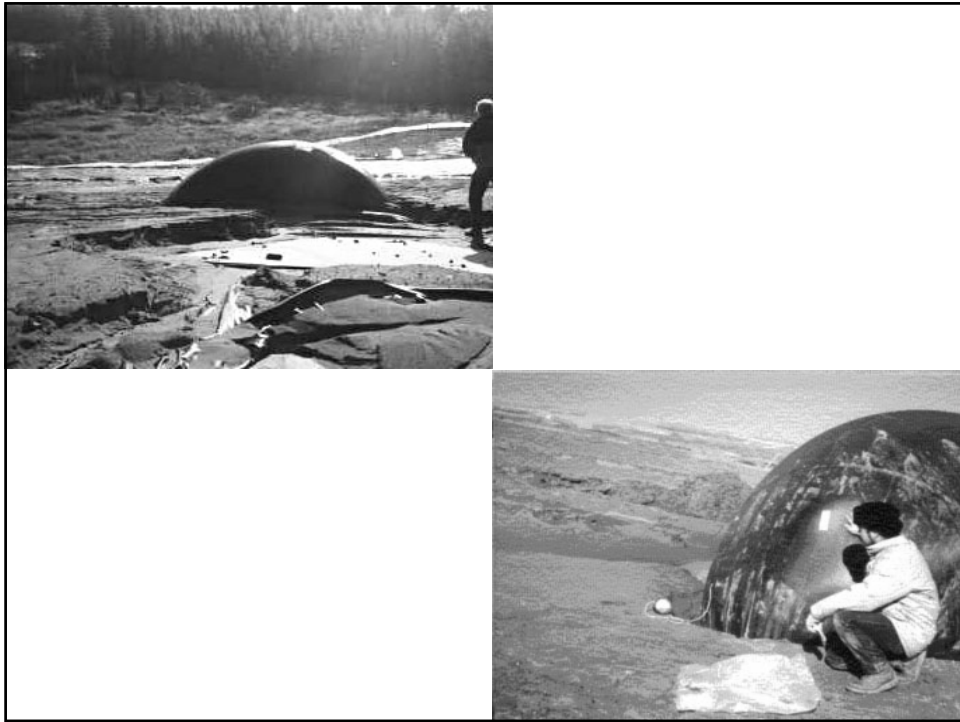
$$k t = \theta_{\text{reqd}} = q / (i \times W) = 2.7 \cdot 10^{-5} / (0.05 \times 1.0) = 5.4 \cdot 10^{-4} \text{ m}^2/\text{min}$$

Step 4: Determine factor of safety, FS

$$FS = \theta_{\text{allow}} / \theta_{\text{reqd}} = 7.0 \cdot 10^{-4} / 5.4 \cdot 10^{-4} = 1.3$$

1.3 < 3.0 not acceptable (i.e geocomposite is needed)





Geotextile Gas Collector Design

- If gas generation is low, NW GT can be used

$$FS = \frac{Q_{\text{allow}}}{Q_{\text{reqd}}}$$

Where:

Q_{allow} = radial flow rate

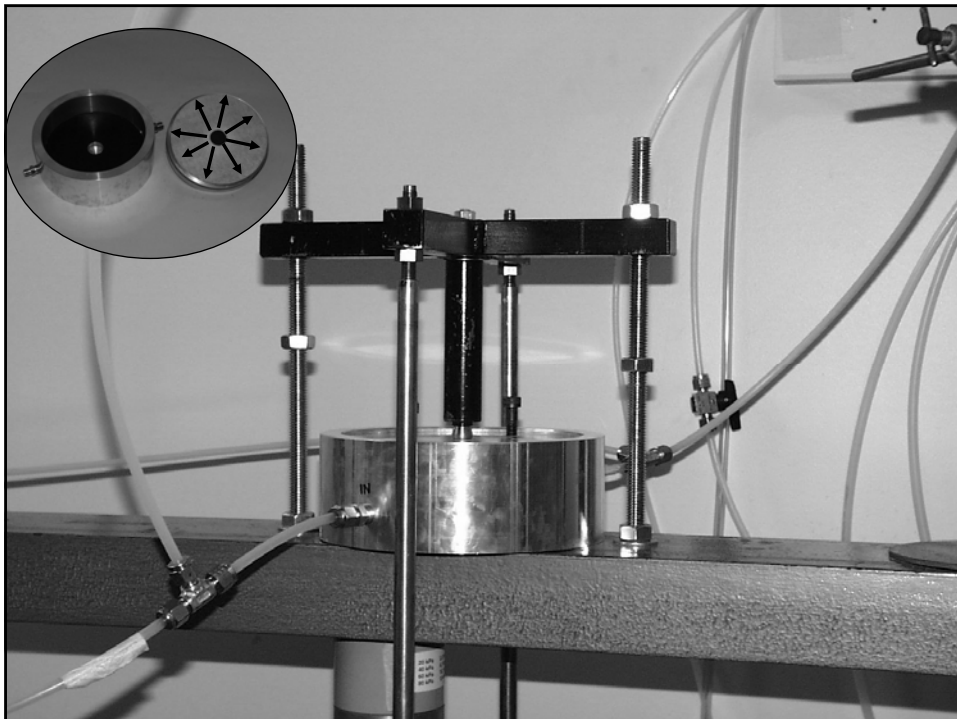
Q_{reqd} = gas generation rate

Typically, 550+g/m² should be adequate

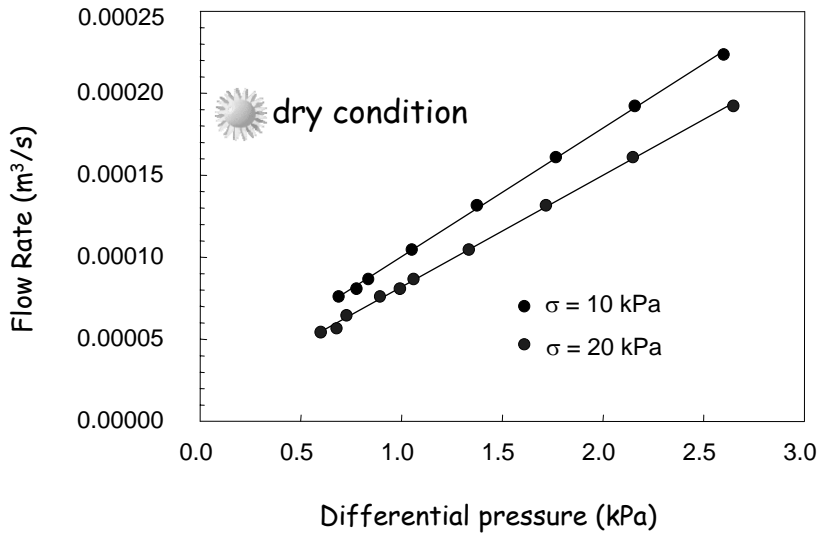
Grading and venting are critical

- Evaluate vertical stress conditions. Use overburden pressure from thickness of cap.
- Radial flow of gas under operating conditions (Q_{all})
- Estimate gas generation rate (Q_{req})
- Calculate transmission requirement for the geotextile ($\Phi > Q_{req} \times \sin \beta$, if on slope)

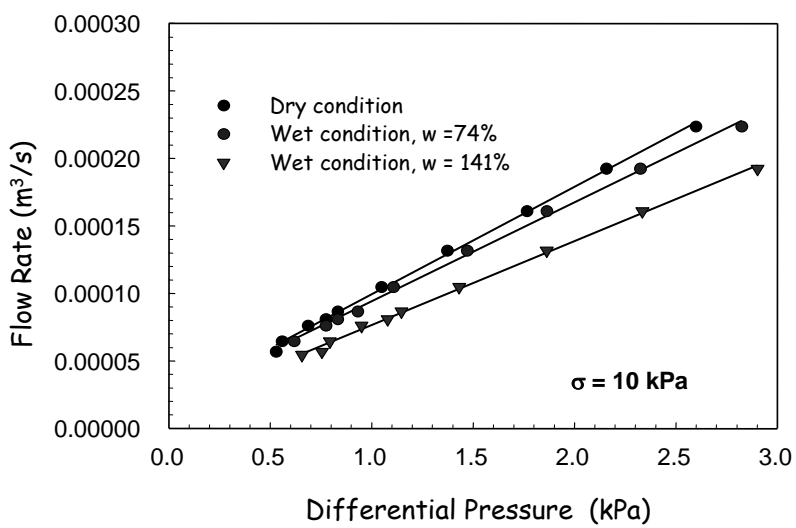
Prepare specifications based on controlling GTX requirements. (transmissivity, mass/unit area, constructibility & durability requirements).



Relation between gas flow rate and differential pressure



Relation between gas flow rate and differential pressure



Example

Let's consider a landfill with an average waste depth of 20 m. The waste is compacted to a density ρ_w of about 1000 kg/m³. Landfill gas generation G_{gr} is about 1.2 to 7.5 10⁻³ m³/kg/year (Emcon, 1980). Check if a given NWGT is suitable as gas collector under the landfill cover area.

GT Mass/area = 600 g/m², thickness, t= 0.005m

Step1: Boundary Conditions:

Vertical stress =20 kPa (typical of cover systems)

Step2: In plane flow rate through GT under 20 kPa load

Dry : $Q_{allow} = 5.5 \cdot 10^{-5} \text{ m}^3/\text{s}$; $\Psi_{allow} = 4.2 \cdot 10^{-7} \text{ m}^2/\text{s}$

Wet: $Q_{allow} = 2.2 \cdot 10^{-5} \text{ m}^3/\text{s}$; $\Psi_{allow} = 1.9 \cdot 10^{-7} \text{ m}^2/\text{s}$

Step 3: Generation rate, assume

$G_{gr} = 6 \cdot 10^{-3} \text{ m}^3/\text{kg}/\text{year} = 1.9 \cdot 10^{-10} \text{ m}^3/\text{kg}/\text{s}$

$Q_{reqd} = G_{gr} \times V_w \times r_w = 3.8 \cdot 10^{-6} \text{ m}^3/\text{s}$

Step4: $FS_{dry} = Q_{all}/Q_{req} = 14.5$

$FS_{wet} = Q_{all}/Q_{req} = 5.8$

Conclusions

- ✓ **No standard solutions. Each application asks for individual design.**
- ✓ **Geosynthetic solutions allow economic and effective constructions.**
- ✓ **There is no one size to fit them all**
- ✓ **A good performance will be more function of installation quality.**