LAWTIG Seminar :

What it takes to build a landfill

Geosynthetics in Landfills

Deon Stipp

Kaytech

G.N. R 636 “Norms and Standards”

A recap in terms of geosynthetics

Some Important New Requirements

The following containment barrier requirements must be included in an application for approval of a landfill site or cell –

(a) Design reports and drawings shall be certified by a registered, professional civil engineer prior to submission to the competent authority;

(b) Service life considerations shall be quantified taking into account temperature effects on containment barriers;

(c) Total solute seepage (inorganic and organic) shall be calculated in determining acceptable leakage rates and action leakage rates;

(d) Alternative elements of proven equivalent performance may be considered, such as the replacement of-

(i) granular filters or drains with geosynthetic filters or drains;

(ii) protective soil layers with geotextiles;

(iii) clay components with geomembranes or geosynthetic clay liners;

Some Important New Requirements (Cont.)

The following containment barrier requirements must be included in an application for approval of a landfill site or cell –

(e) All drainage layers shall contain drainage pipes of adequate size, spacing and strength to ensure atmospheric pressure within the drainage application for the service life of the landfill;

(f) Alternative design layouts for slopes exceeding 1:4 (vertical: horizontal) may be considered provided equivalent performance is demonstrated;

(g) Construction Quality Assurance during construction;

(h) Geosynthetic materials shall comply with relevant South African National Standard specifications, or any prescribed management practice or standards which ensure equivalent performance; and

(i) Consideration of the compatibility of liner material with the waste stream, in particular noting the compatibility of natural and modified clay soils exposed to waste containing salts.

What *Is* A Geosynthetic ?

"A Planar, Polymeric (Synthetic or Natural) Material,

Used In Contact With Soil / Rock . .

And / Or Any Other Geotechnical Material In Civil Engineering Applications."

International Geosynthetics Society (IGS) (www.geosyntheticssociety.org)

Geosynthetics Interest Group of South Africa (GIGSA) (www.gigsa.org)

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PET

Polyethylene
Terephthalate

HDPE

High Density
Polyethylene

PVC

Polyvinyl
Chloride

LDPE

Low Density
Polyethylene

PP

Polypropylene

PS

Polystyrene

The 6 Main Functions Of Geosynthetics

- Filtration
- Drainage
- Separation
- Reinforcement
- Barrier
- Erosion Control

Geosynthetics Include:

- Geotextiles
- Geogrids
- Geopipes
- Geocells
- Geosynthetic Clay Liners (GCLs)
- Geocontainers
- Geomembranes
- Geocomposites

This Brings Us To

Geosynthetics used at Karwyderskraal landfill Cell 4

Geosynthetics used

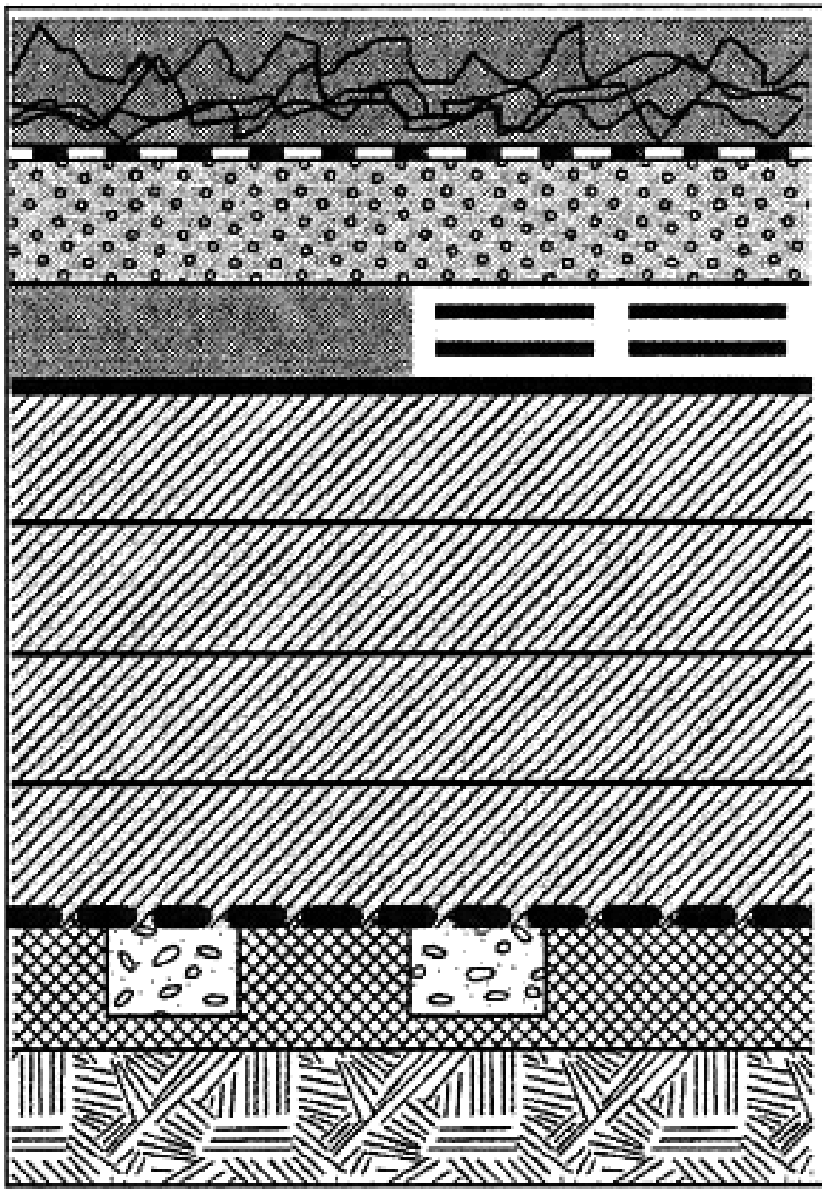
- Geotextiles
- Geogrids
- Geopipes
- Geocells
- Geosynthetic Clay Liners (GCLs)
- Geocontainers
- Geomembranes
- Geocomposites

Geomembranes

Geotextiles in landfills

- Liner Protection
- Separation

(b) Class B Landfill:



Waste body

Geotextile
150 mm Stone leachate
collection system

100 mm Protection layer of silty sand
or a Geotextile of equivalent performance

1,5 mm HDPE Geomembrane

Primary
Composite
Liner

600 mm Compacted clay
liner (in 4 x 150 mm layers)

Max Outflow 300 mm/y

(1 x 10^{-8} m/s)

Under drainage and monitoring system
and 150 mm Base preparation layer

In situ soil

Liner protection with geotextiles

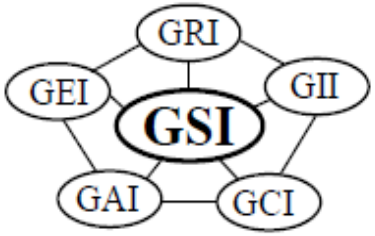

Picture Courtesy of Golder Associates / WBHO / Aquatan

Considerations for liner protection geotextiles

- Availability of sand
- Constructability of a sand layer, eg. on slopes
- Stresses imposed on liner, ie, confining pressure - waste height, construction machinery, rock size and shape
- Interface Shear between different layers
- In plane flow capacity
- Type of geotextile – woven / nowoven
- Specification and Manufacturing Quality Control

Specification and Quality Control

Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441



Rev. 2: March 3, 2016
Revision Schedule: pg. 7

GRI Test Method GT12(a)* - ASTM Version

Standard Specification for

"Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials"

GRI GT 12

Table 1(b) – Required Properties, Test Methods and Values for Geotextiles Used as Geomembrane Protection (or Cushioning) Materials

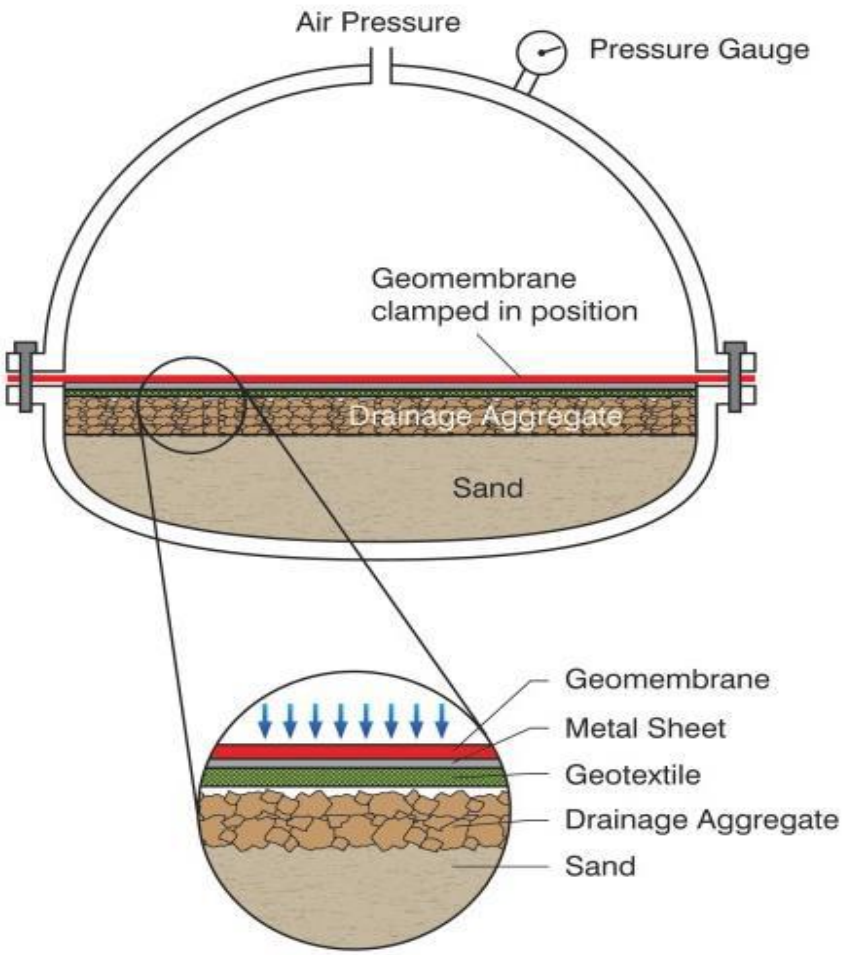
Property[1]	Test Method ASTM	Unit	Mass/Unit Area (g/m^2)					
Mass per unit area	D5261	g/m^2	340	406	542	812	1080	2000
Grab tensile strength	D4632	kN	1.02	1.33	1.64	2.00	2.25	2.80
Grab tensile elongation	D4632	%	50	50	50	50	50	50
Trap. tear strength	D4533	kN	0.42	0.51	0.64	0.89	0.96	1.27
Puncture (CBR) strength	D6241	kN	3.11	3.56	4.00	4.90	7.56	10.60
UV resistance[2]	D7238	%	70	70	70	70	70	70

Notes:

(1) All values are MARV except UV resistance; it is a minimum value.

(2) Evaluation to be on 50 mm strip tensile specimens per ASTM D5035 after 500 lt. hrs. exposure.

Karwyderskraal 3rd Party Conformance testing



ASTM D5514 – Large Scale Hydrostatic Puncture Testing of Geosynthetics apparatus

Strain analysis as per Hornsey & Wishaw method

Tested to 500kPa

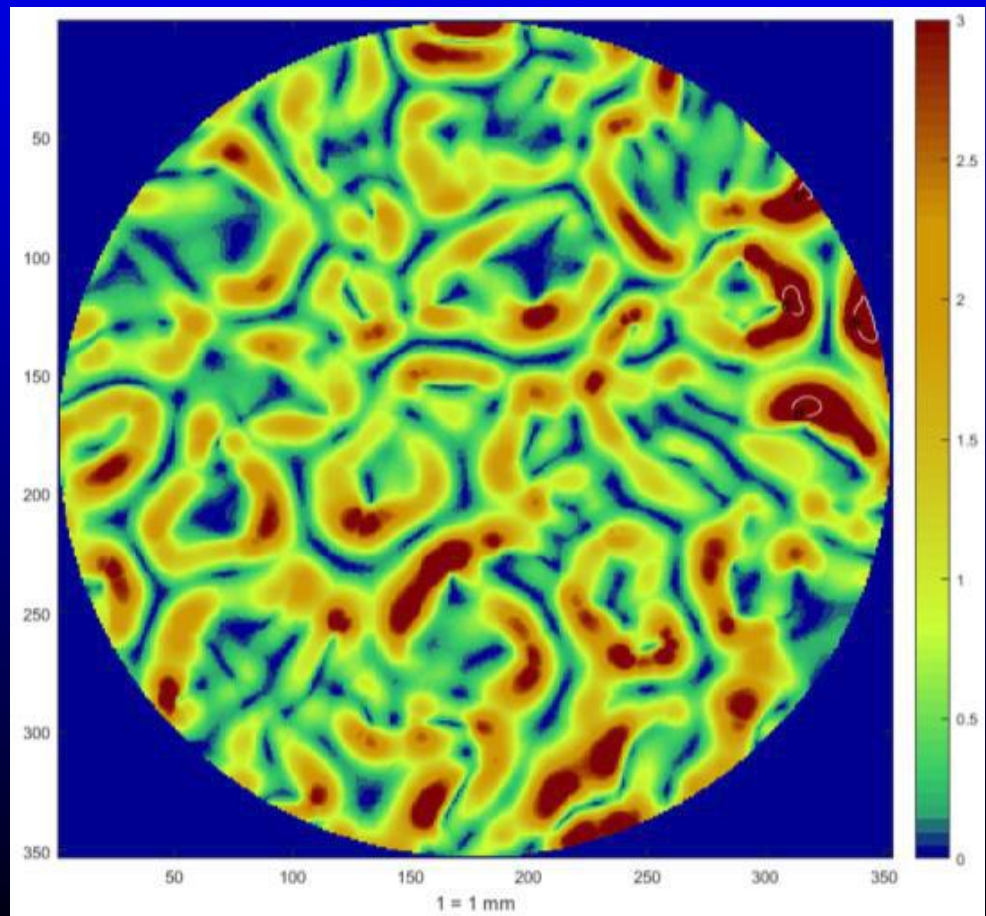
Protection geotextile

Aggregate mould

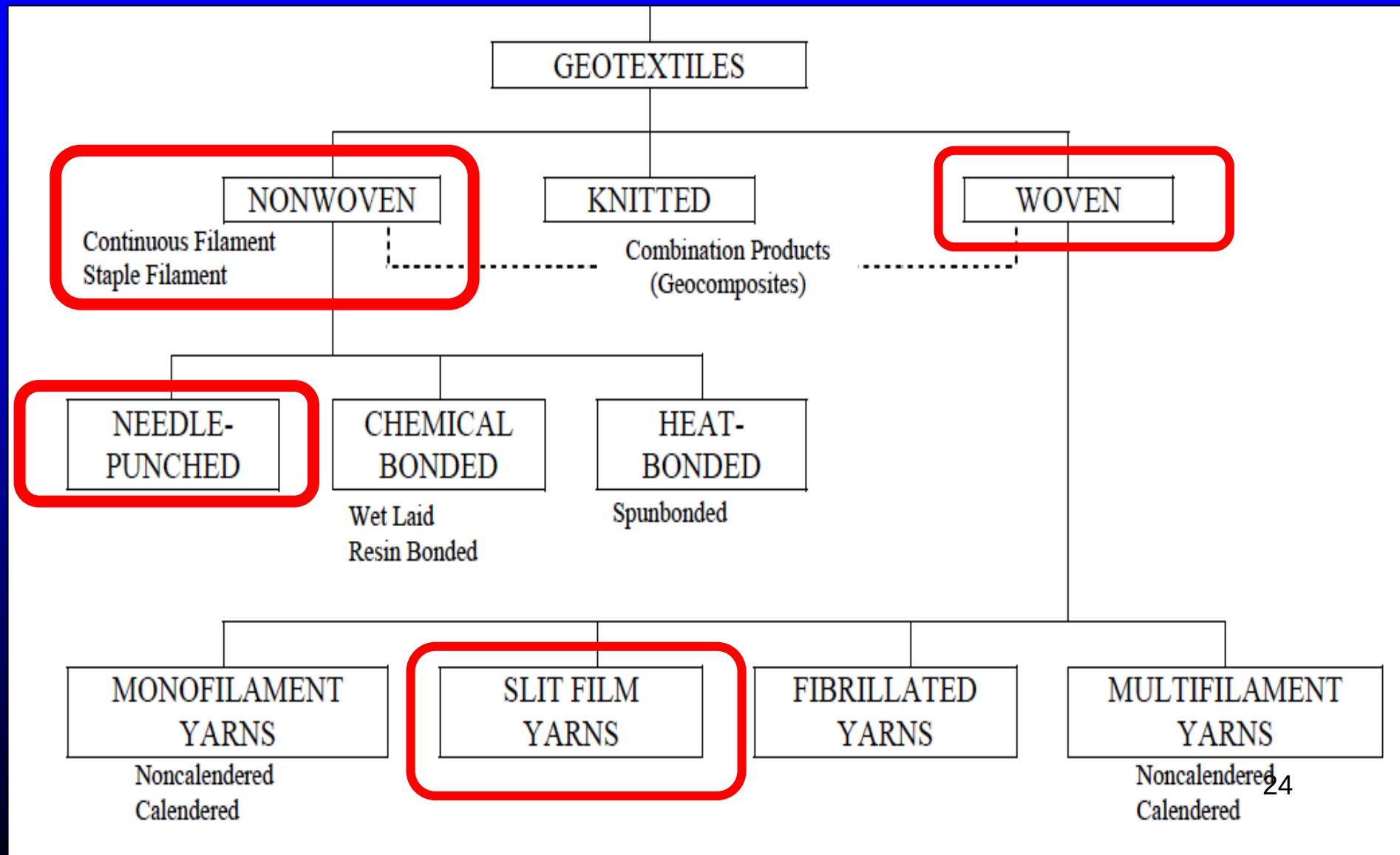
Laser scanning of surface

0,3mm Aluminium

Strain distribution



Types of Geotextile



Manufacturing Techniques

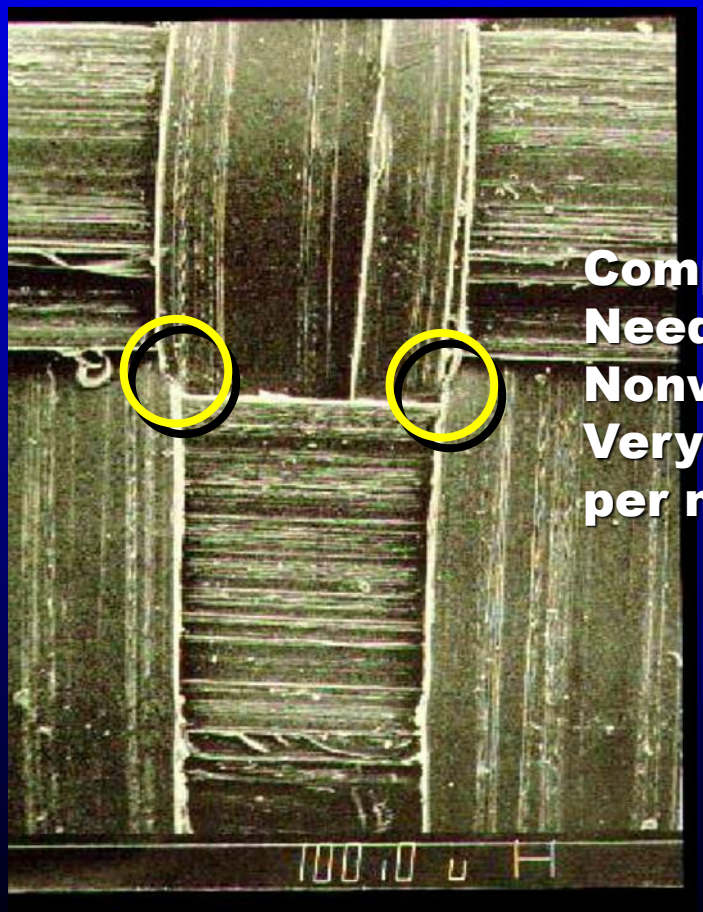
1.Woven Geotextiles

- **Woven Flat Tape**
  (Usually HIGH Tensile Modulus & Usually Made of PP)

- **Low Permittivity**
- **High Strength**

Woven Slit Film Geotextile
(Magnified x 100)

Drainage Grades
= ± 20-140$_L$/m^2/s



Compared to Needlepunched Nonwoven, Very Few Pores per m^2

Manufacturing Techniques

2. Nonwoven Geotextiles

- **Continuous Filament, Needlepunched (PP or PET)**
- **Mechanically Bonded** ***(e.g. "bidim", "Polyfelt" etc.)***
  (Usually LOW Tensile Modulus)

Non -Woven Continuous Filament Needle Punched Geotextile

(Magnified x 100)

80% Porous

Drainage Grades

= 280 - 230 ℓ/m²/s)

Characteristics Of Needlepunched Nonwoven Geotextiles

- **Isotropic** (Nearly Equally Strong In All Directions)

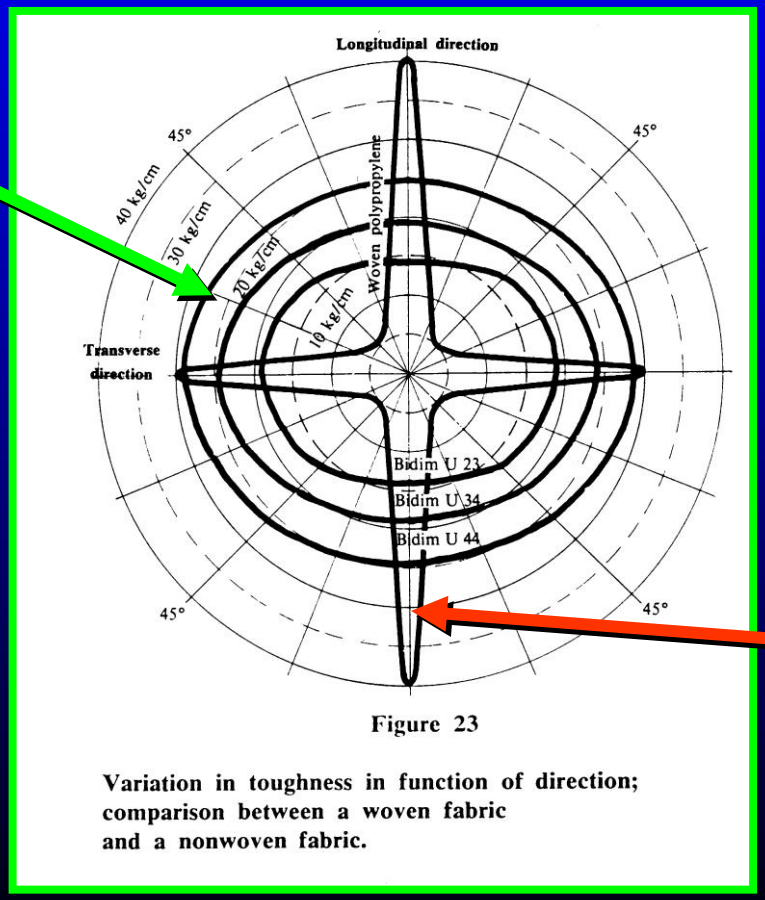
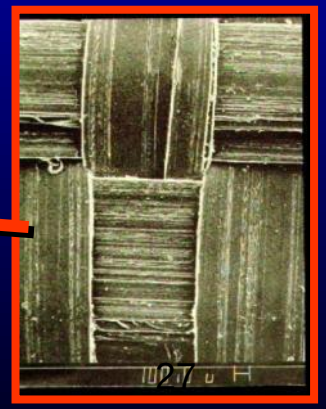


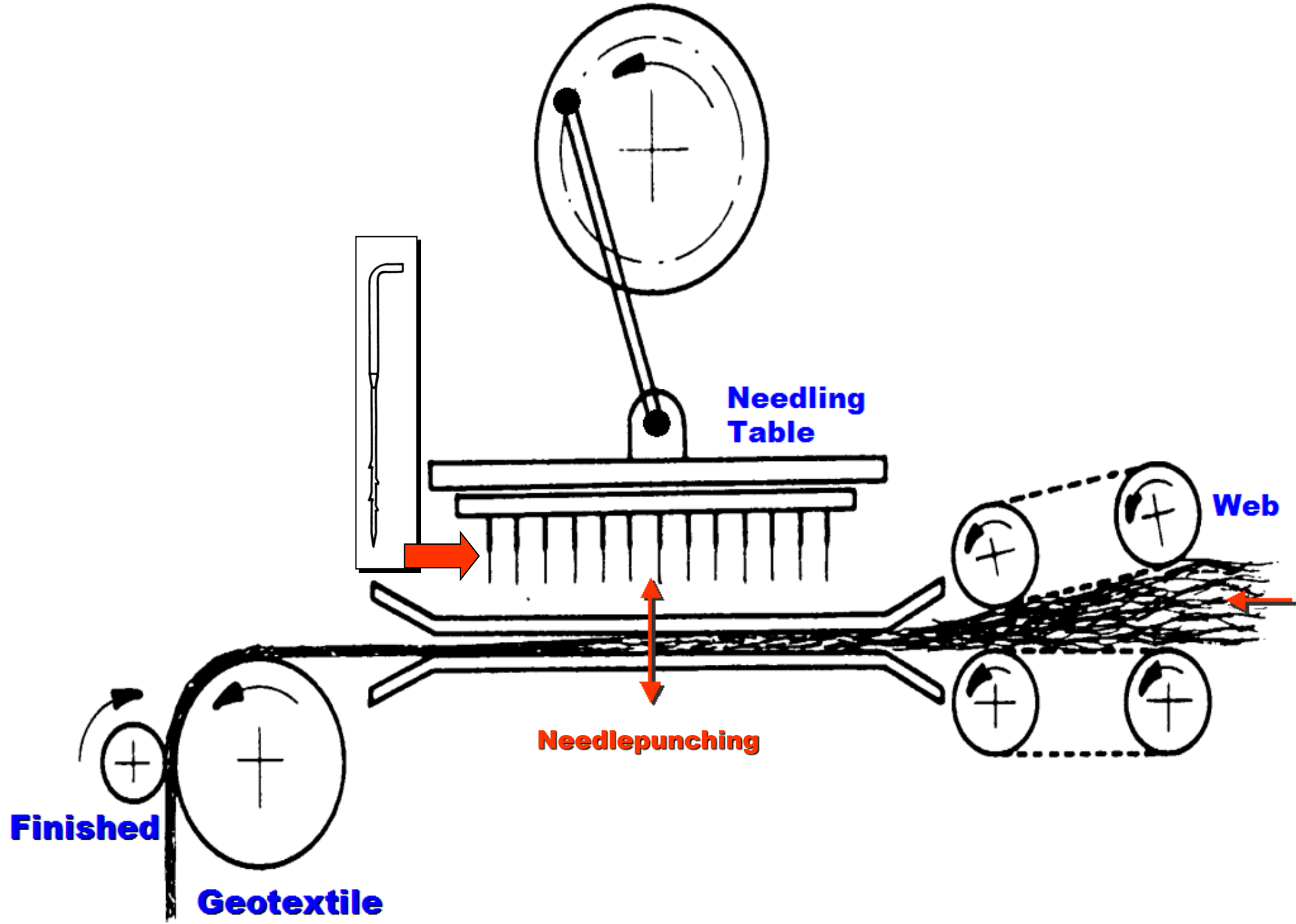
Figure 23

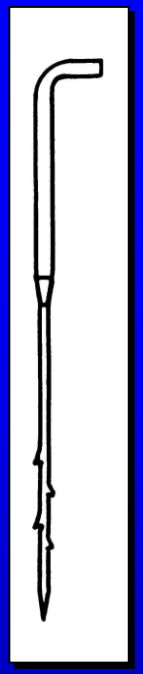
Variation in toughness in function of direction; comparison between a woven fabric and a nonwoven fabric.

Woven Geotextiles Are Anisotropic



Manufacture of Needlepunched Nonwoven Geotextiles


Needling
Table
Web
Needlepunching
Finished
Geotextile

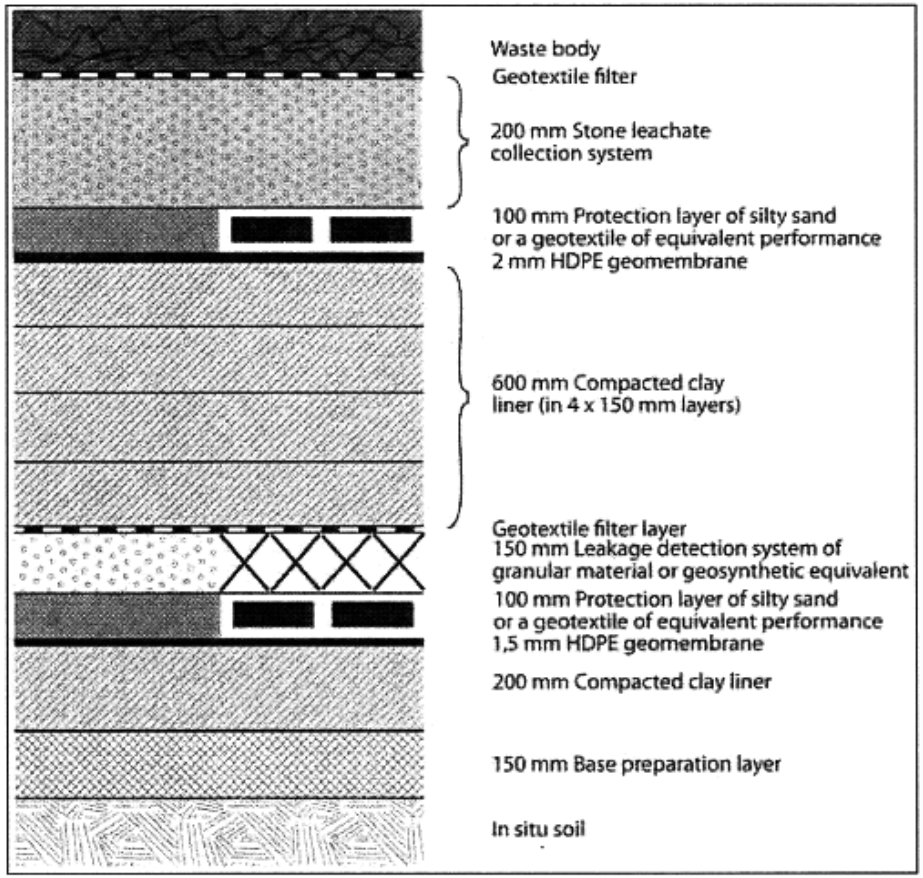



Needlepunched


Finished Geotextile

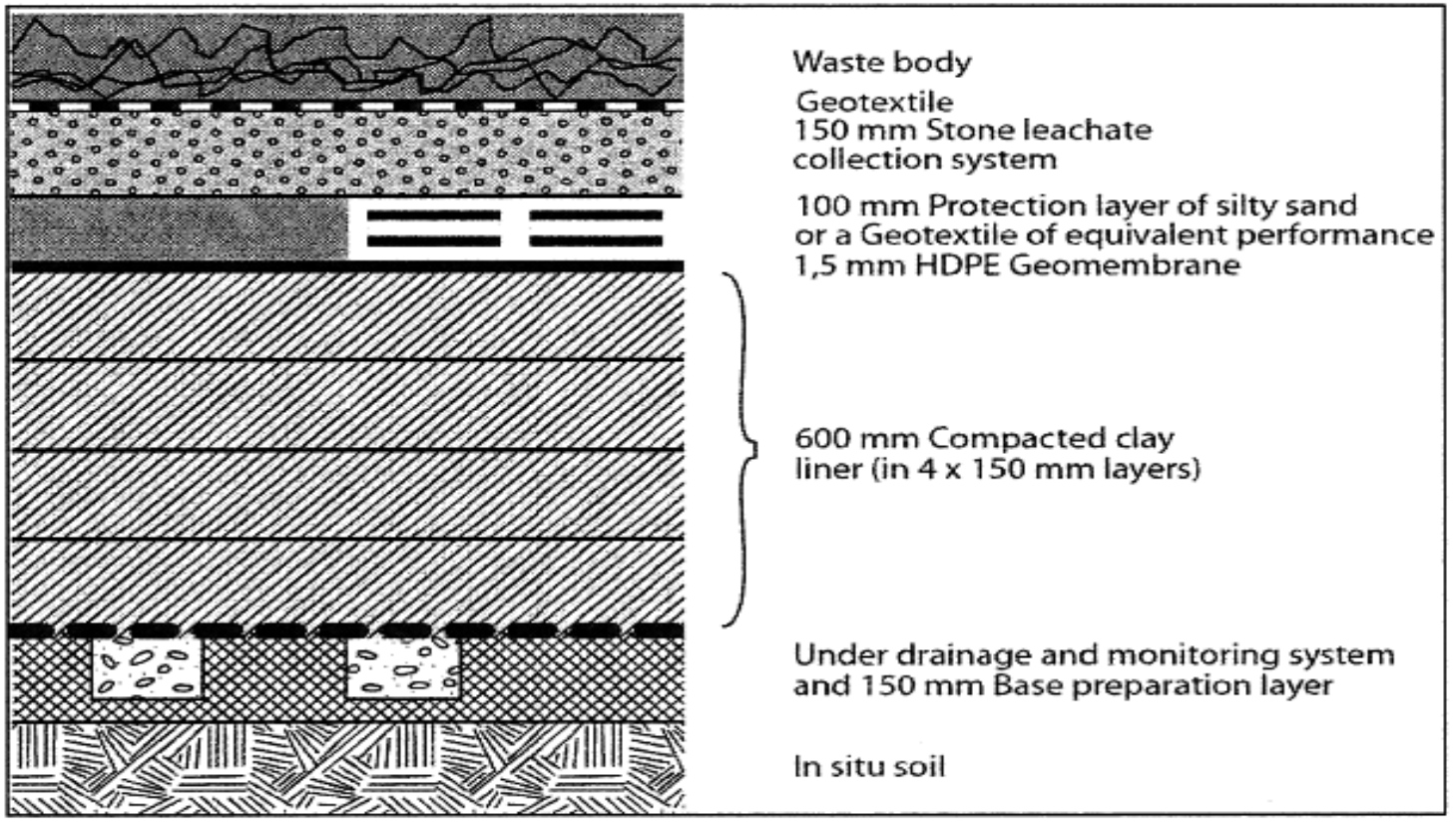
Separation geotextiles

(a) Class A Landfill:



Separation geotextiles

(b) Class B Landfill:



Considerations for separation geotextiles

- Strength properties
- Elongation
- Permeability
- Pore size
- Specification and MQC

Specification and Quality Control

Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441

Revision 4: June 20, 2017
Revision Schedule on pg. 9

GRI GT13(a) – ASTM Version*

Standard Specification for

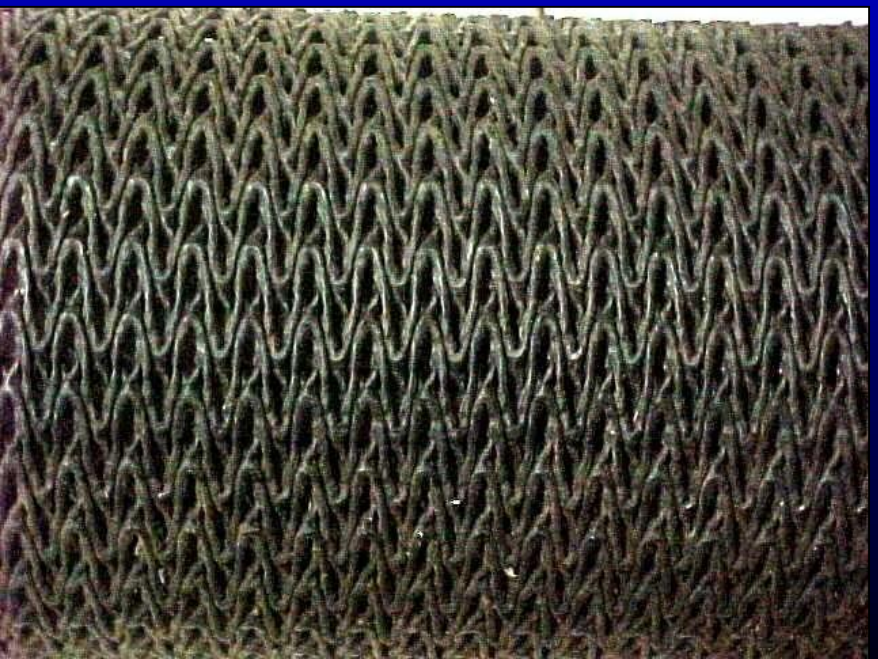
"Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate"

GRI GT 13

Table 2(b) – Geotextile Properties Class 2 (Moderate Survivability)

Property[1]	ASTM Test	Unit	Elongation < 50%	Elongation ≥ 50%
Grab Tensile Strength	D 4632	N	1100	700
Trapezoid Tear Strength	D 4533	N	400	250
CBR Puncture Strength	D 6241	N	2250	1400
Permittivity	D 4491	sec-1	0.02	0.02
Apparent Opening Size	D 4751	mm	0.60	0.60
Ultraviolet Stability[2]	D 7238	% Str. Ret. @ 500 lt. hrs.	70	70

Geopipes



Geocells

Geocells filled with concrete

Geocells filled with soilcrete

Picture Courtesy of Engineered Linings

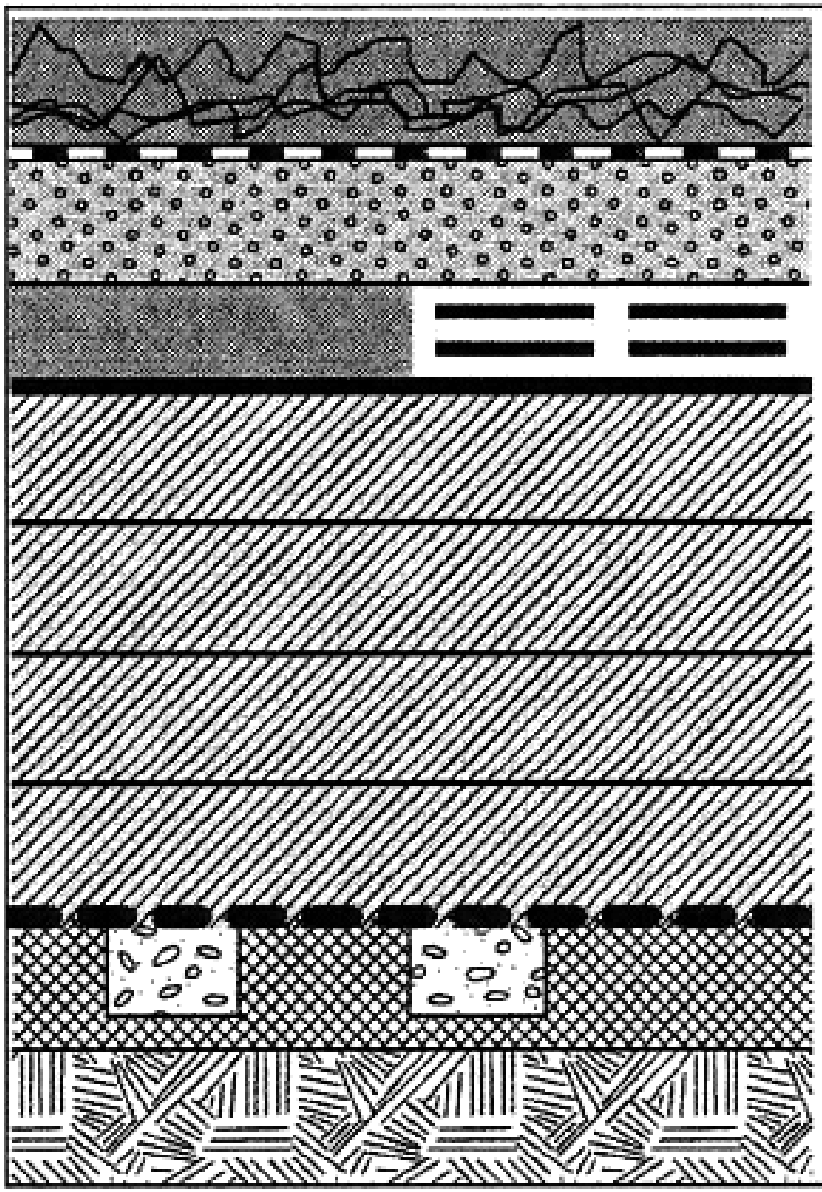
Other Geosynthetics in Landfills

Geosynthetic Clay Liner (GCL)

as geosynthetic alternative to

Compacted Clay Liner (CCL)

(b) Class B Landfill:



Waste body

Geotextile
150 mm Stone leachate
collection system

100 mm Protection layer of silty sand
or a Geotextile of equivalent performance

1,5 mm HDPE Geomembrane

Primary
Composite
Liner

600 mm Compacted clay
liner (in 4 x 150 mm layers)

Max Outflow 300 mm/y

(1 x 10^{-8} m/s)

Under drainage and monitoring system
and 150 mm Base preparation layer

In situ soil

What *Is* a Geosynthetic Clay Liner ?

"An assembled structure of geosynthetic materials and low hydraulic conductivity earth material (clay), in the form of a manufactured sheet, used in civil engineering applications.."

(Recommended Descriptions of Geosynthetics Functions, Geosynthetics Terminology, Mathematical and Graphical Symbols 5th Edition September 2009)

International Geosynthetics Society (IGS) Definition

(www.geosyntheticssociety.org)

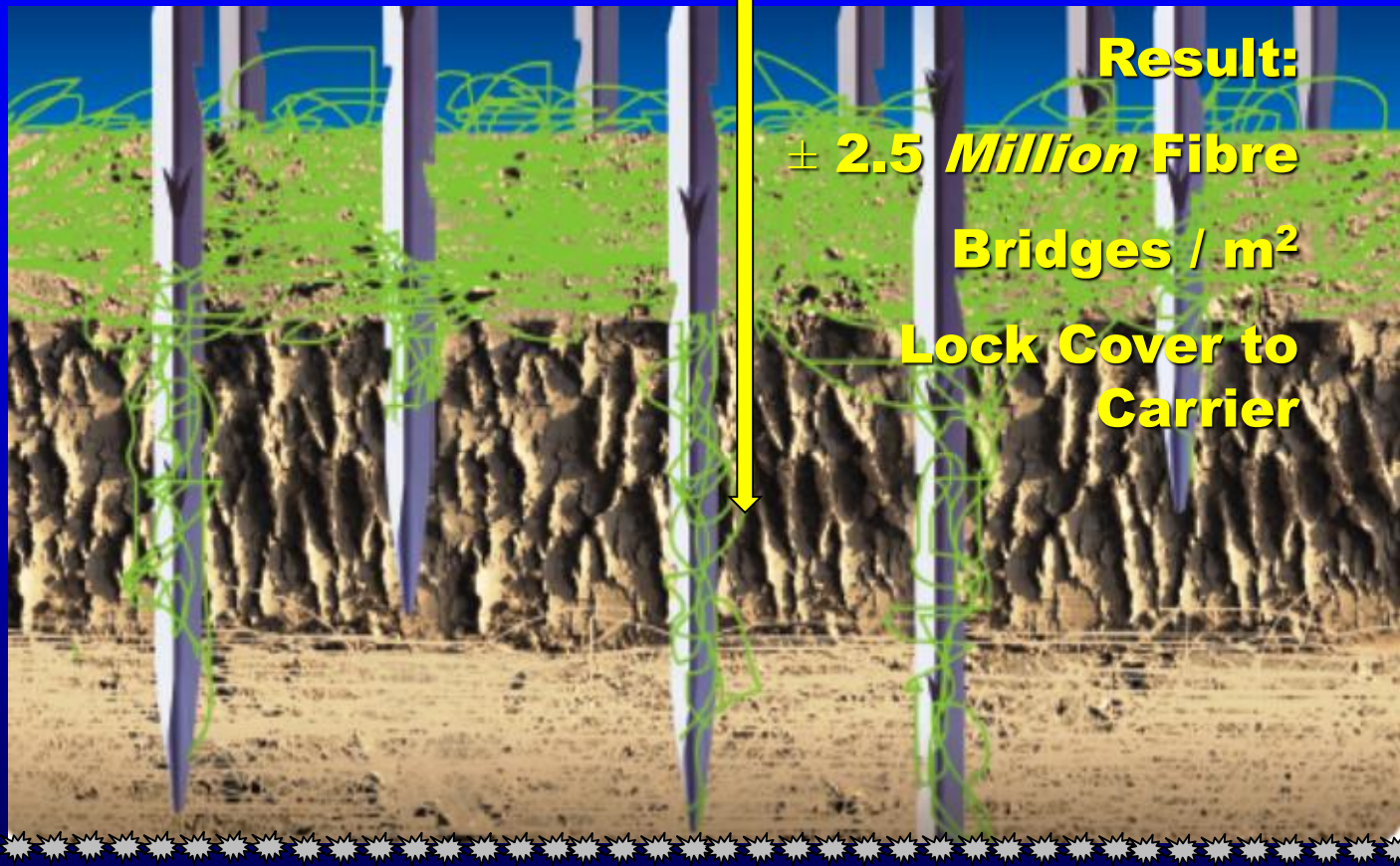
Nonwoven Geotextile Cover Fabric

3.6 to 5.0 kg/ m^2

Bentonite Powder (Depending on Grade)

Woven Carrier Fabric

(Can include Nonwoven as Well)



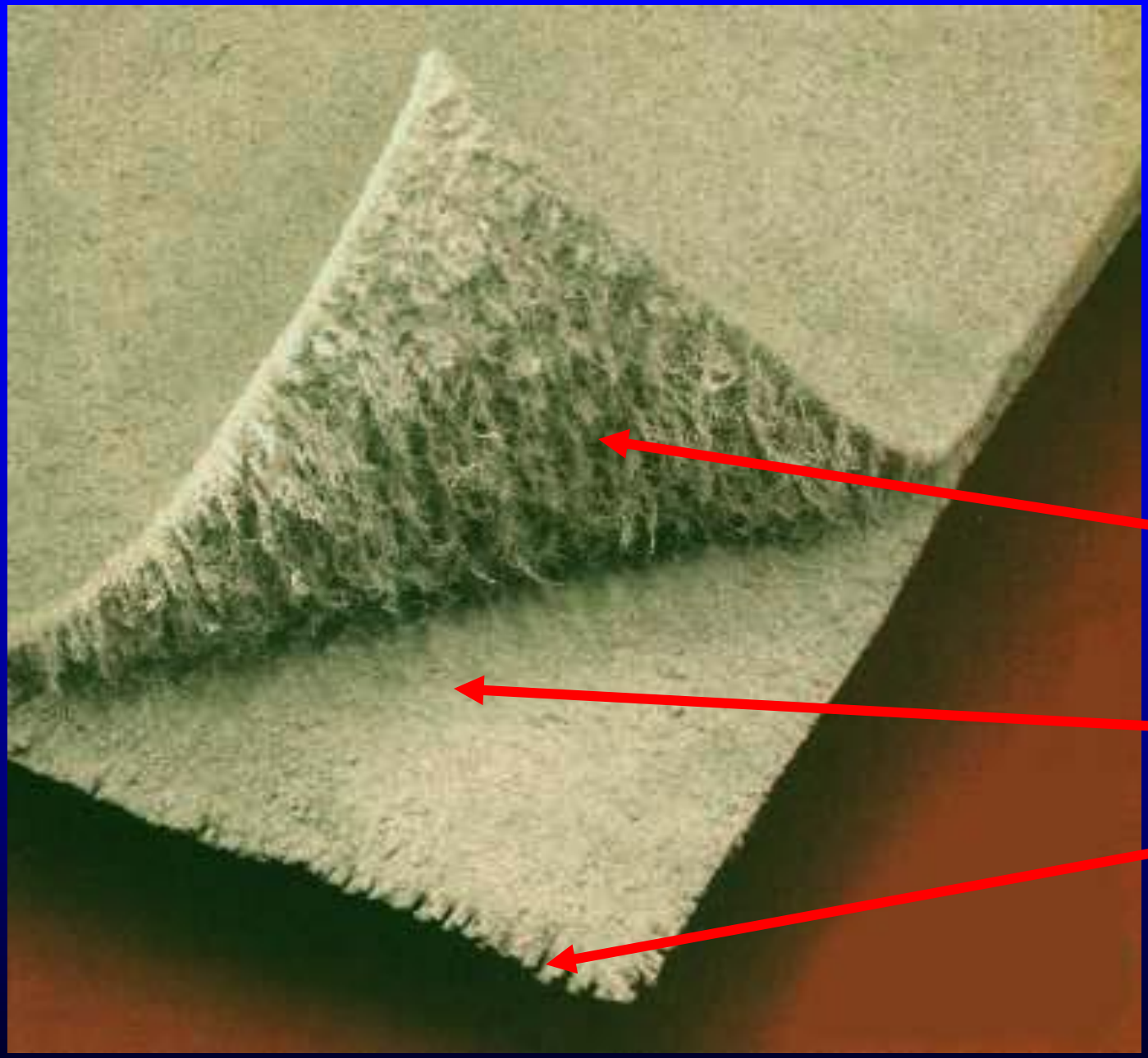
Barbed Needles Cycle Through Composite,

Result:

± 2.5 *Million* Fibre Bridges / m^2

Lock Cover to Carrier

***Thermal Locking®* Heat Treatment Provides Rough, High-Friction Surface, and Enhances Peel Strength**


Needle
punched
fibres
Bentonite
Woven

HYDRATED VS UNHYDRATED GCL (UNCONFINED)

SELF-HEALING ABILITIES

Considerations for GCL's

- Availability and Quality of clay
- Constructability of Compacted Clay Liner (CCL), eg. on steep slopes and over drainage layers
- Simple installation
- Airspace considerations
- Quality control - On-site vs factory controlled
- Interface Shear
- Internal shear – different grades
- Chemical compatibility
- Specification and MQC

Specification and Quality Control

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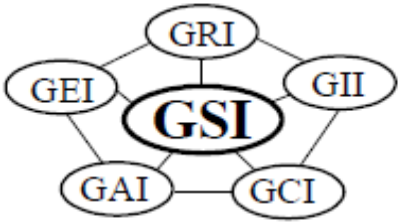


Original - May 16, 2005
Rev. #2 – July 26, 2010
Rev. #3 - March 14, 2016
Rev. #4 - March 28, 2016
Revision Schedule on pg. 12

GRI-GCL3*

Standard Specification for

"Test Methods, Required Properties, and Testing Frequencies of Geosynthetic Clay Liners (GCLs)"

GRI GCL 3

GRI-GCL3 Spec - S.I. (Metric) Units

Table 1(a) – Specification for Geosynthetic Clay Liners (GCLs)

Property	ASTM Test Method	Reinforced GCL			Non-Reinforced GCL			Testing Frequency
		GT-Related	GT Polymer Coated	GM-GF Related	GT-Related	GT Polymer Coated	GM-GF Related	
Clay (as received)								
swell index (ml/2g)	D5890	24	24	24	24	24	24	50 tonnes
fluid loss (ml)[1]	D5891	18	18	18	18	18	18	50 tonnes
Geotextiles (as received)								
cap fabric (nonwoven) - mass/unit area (g/m^2)[2]	D5261	200	200	200	100	100	n/a/100	20,000 m^2
cap fabric -(woven) - mass/unit area (g/m^2)	D5261	100	100	100	100	100	100	20,000 m^2
carrier fabric (nonwoven composite) - mass/(g/m^2)[2]	D5261	200	200	200	100	100	n/a/100	20,000 m^2
carrier fabric (woven) - mass/unit area (g/m^2)	D5261	100	100	100	-	-	-	20,000 m^2
coating - mass/unit area (g/m^2)[3]	D5261	n/a	200	n/a	n/a	200	n/a	4,000 m^2
Geomembrane/Geofilm (as received)								
thickness[4] (mm)	D5199/D5994	n/a	n/a	0.40/0.50/0.10	n/a	n/a	0.40/0.75/0.10	20,000 m^2
density (g/cc)	D1505/D792	n/a	n/a	0.92	n/a	n/a	0.92	20,000 m^2
break tensile strength, MD&XMD (kN/m)	D6693	n/a	n/a	n/a	n/a	n/a	6.0	20,000 m^2
break tensile strength, MD (kN/m)	D882	n/a	n/a	2.5	n/a	n/a	2.5	20,000 m^2
GCL (as manufactured)								
mass of GCL (g/m^2)[5]	D5993	4000	4050	4100	4000	4050	4100	4,000 m^2
mass of bentonite (g/m^2)[5]	D5993	3700	3700	3700	3700	3700	3700	4,000 m^2
moisture content[1] (%)	D5993	35	35	35	35	35	35	4,000 m^2
tensile str., MD (kN/m)	D6768	4.0	4.0	4.0	4.0	4.0	4.0	20,000 m^2
peel strength (N/m)	D6496	360	360	360	n/a	n/a	n/a	4,000 m^2
permeability[1] (m/sec), "or"	D5887	5×10^{-11}	n/a	n/a	5×10^{-11}	n/a	n/a	25,000 m^2
flux[1] (m^3/sec-m^2),	D5887	1×10^{-8}	n/a	n/a	1×10^{-8}	n/a	n/a	25,000 m^2
GCL permeability[1],[6],[7] (m/sec) (max. at 35 kPa)	D6766	1×10^{-8}	n/a	n/a	1×10^{-8}	n/a	n/a	yearly
GCL permeability[1],[6],[7] (m/sec) (max. at 500 kPa)	D6766 mod.	5×10^{-10}	n/a	n/a	5×10^{-10}	n/a	n/a	yearly
Component Durability								
geotextile and reinforcing yarns [8] (% strength retained)	See § 5.6.2	65	65	n/a	65	65	n/a	yearly
geomembrane	See § 5.6.3	n/a	n/a	GM Spec[9]	n/a	n/a	GM Spec[9]	yearly
geofilm/polymer treated[8] (% strength retained)	See § 5.6.4	n/a	85	80	n/a	85	80	yearly

n/a = not applicable with respect to this property

(1) These values are maximum (all others are minimum)

(2) For both cap and carrier fabrics for nonwoven reinforced GCLs; one, or the other, must contain a scrim component of mass ≥ 100 g/m^2 for dimensional stability. This only applies to GM/GCL composites which are exposed to the atmosphere for several months or longer so as to mitigate panel separation.

(3) Calculated value obtained from difference of coated fabric to as-received fabric

(4) First value is for smooth geomembrane; second for textured geomembrane; third for geofilm

(5) Mass of the GCL and bentonite is measured after oven drying per the stated test method

(6) Value represents GCL permeability after permeation with a 0.1 M calcium chloride solution (11.1 g CaCl2 in 1-liter water); for termination criterion see § 5.6.1

(7) Test should be run on the pure bentonite only. Not on polymer modified bentonites.

(8) Value represents the minimum percent strength retained from the as-manufactured value after oven aging at 60°C for 50 days

(9) Durability criteria should follow the appropriate specification for the geomembrane type used; i.e., GRI GM-13 for HDPE, GRI GM-17 for LLDPE or GRI GM-18 for fPP

Table 1: Leakage Rate Through Various Liner Systems (in litres per hectare per day) After Giroud *et al* (1994)

Type of Liner	Hydraulic Head (m)	
	0.01	**0.3**
CCL ($k = 1 \times 10^{-8}$ m/s)	9000	15000
CCL ($k = 1 \times 10^{-9}$ m/s)	900	1500
HDPE Geomembrane	600	3000
GCL ($k = 1 \times 10^{-11}$ m/s, D = 1 cm)	17	270
Composite Liner, GM & CCL, ($k_{CCL} = 1 \times 10^{-9}$ m/s)	0.05	1
Composite Liner, GM & GCL, ($k_{GCL} = 1 \times 10^{-11}$ m/s)	0.002	0.2

Giroud J.P., Badu-Tweneboah K., & Soderman K.L, *"Evaluation of Landfill Liners"*, Fifth International Conference on Geotextiles, Geomembranes and Related Products, Vol. 3, Pages 981-986, 1994. SEAC-IGS. ISBN 981-00-5823-3

By Far the best results are still achieved by a combination of all three. CCL, GCL HDPE

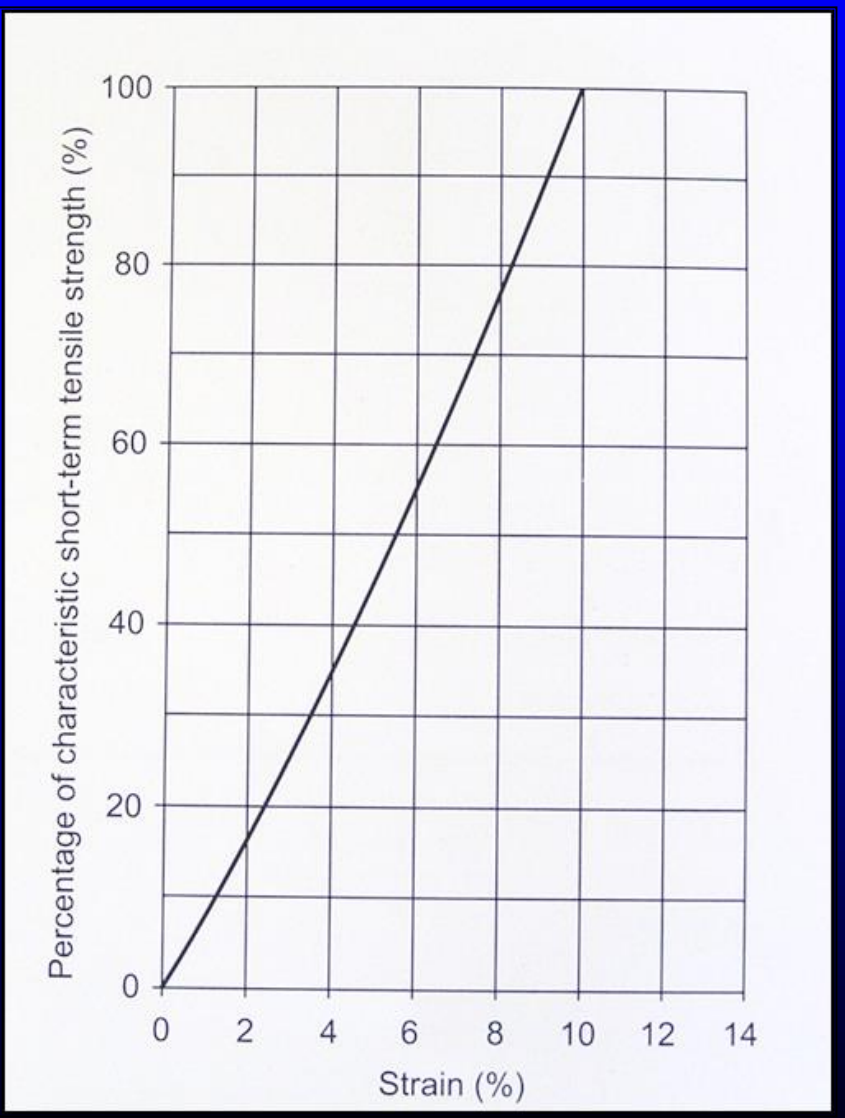

CAT

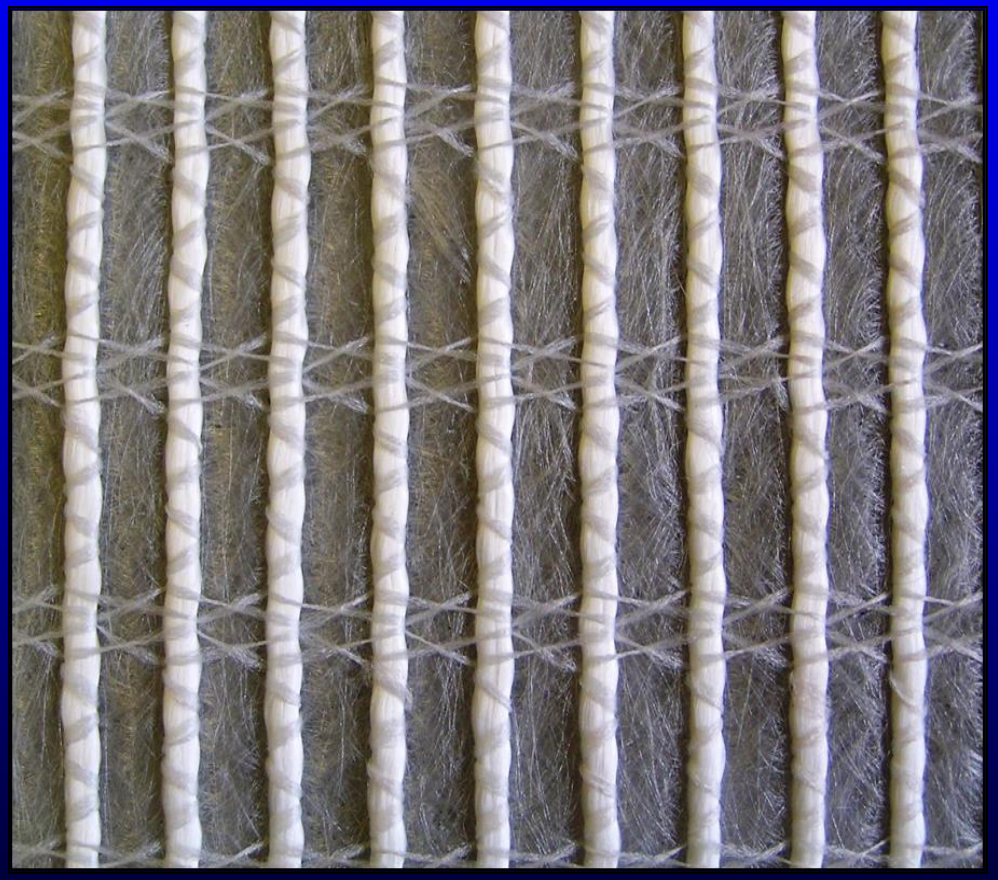
Versatility of a GCL. Non technical installation can easily be done and monitored.

Geogrids

- **Verneer reinforcing**
  - **Unidirectional grids**
- **Basal reinforcing**
  - **Bidirectional grids**

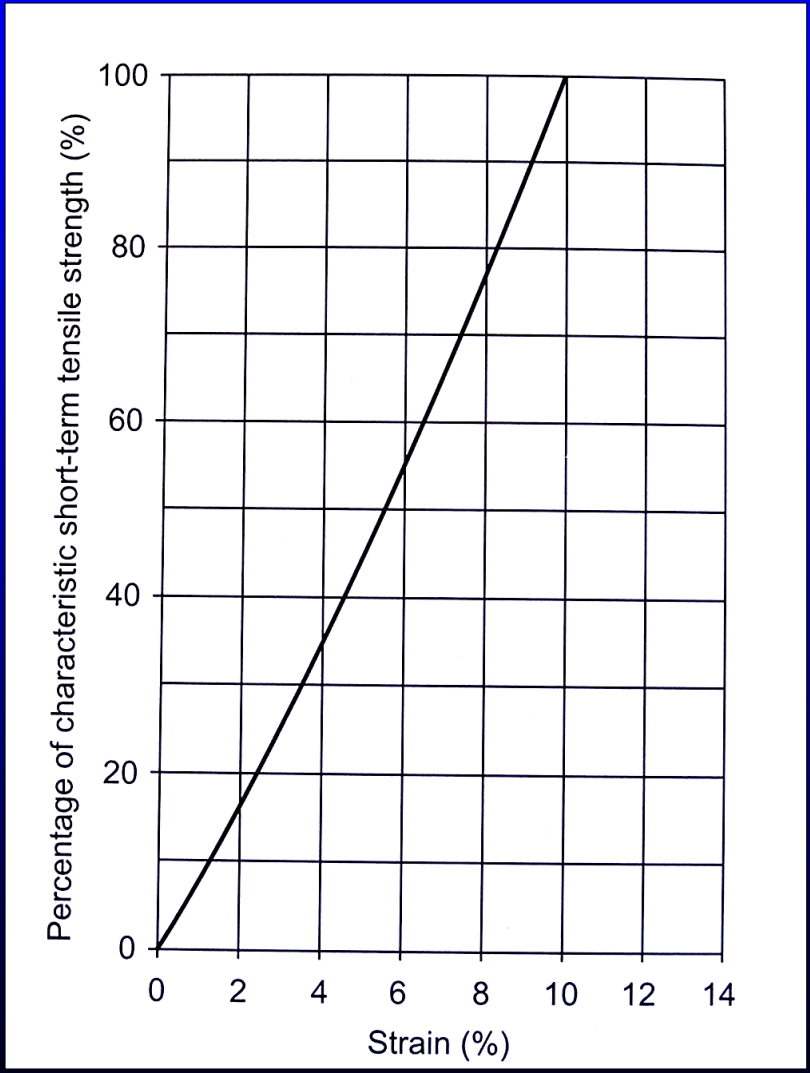
Composite grids

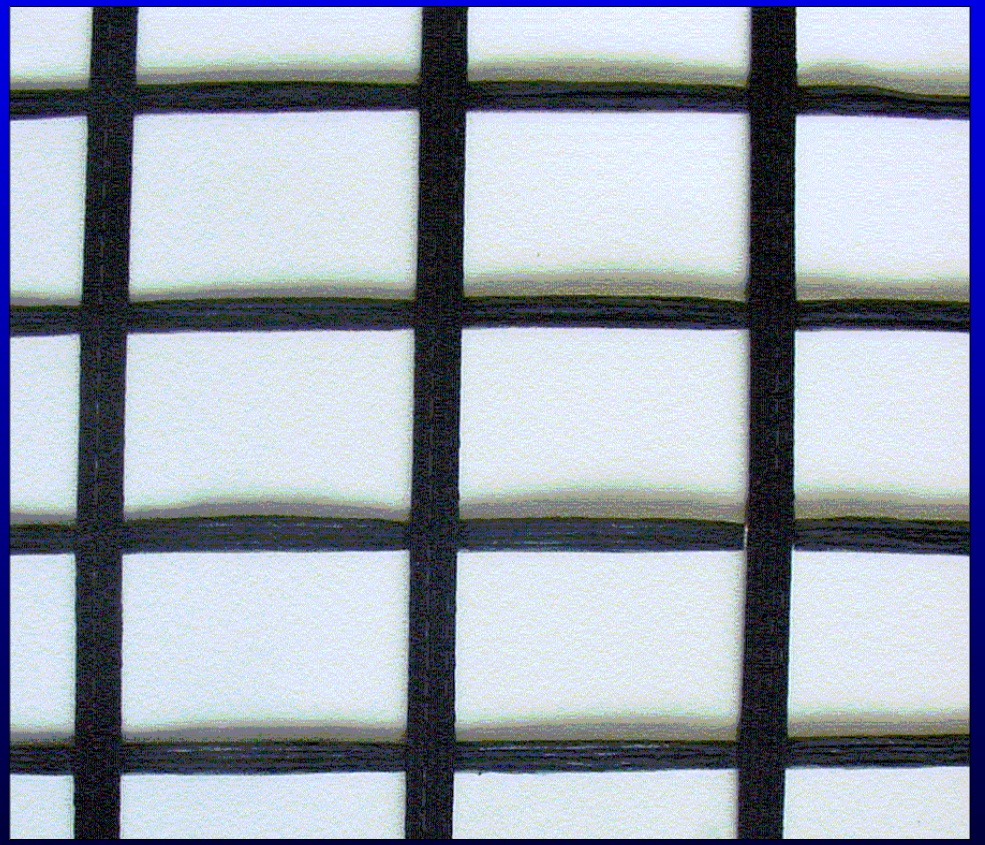




Composite grids

Open grids


Percentage of characteristic short-term tensile strength (%)
100
80
60
40
20
0
0
2
4
6
8
10
12
14
Strain (%)

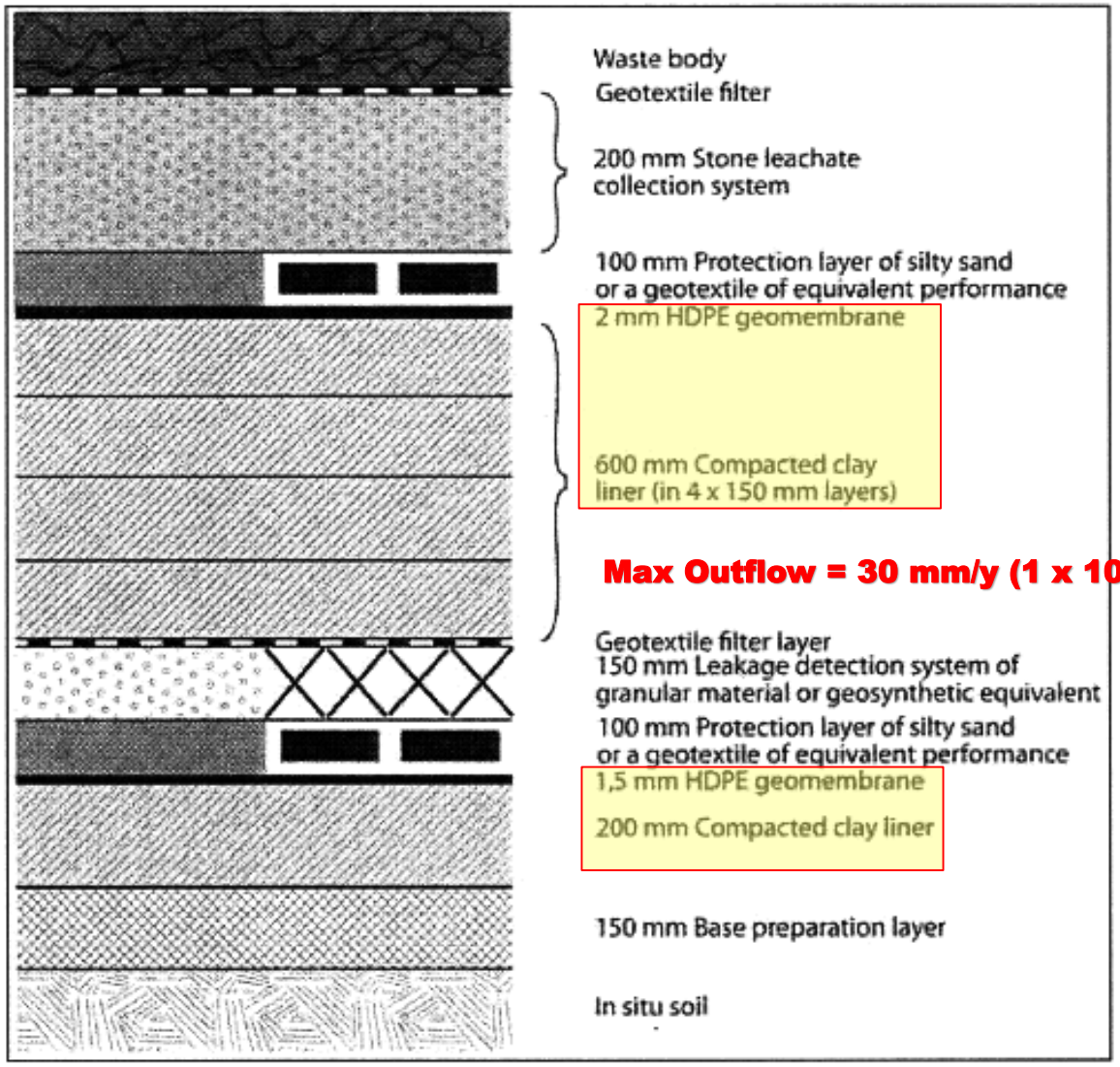


Open grids

Geospacers

- Cuspated sheets
- Geonets

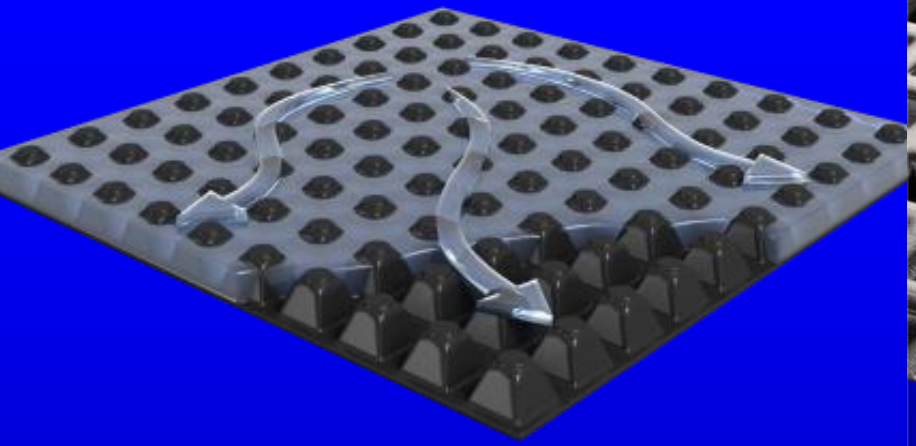
(a) Class A Landfill:

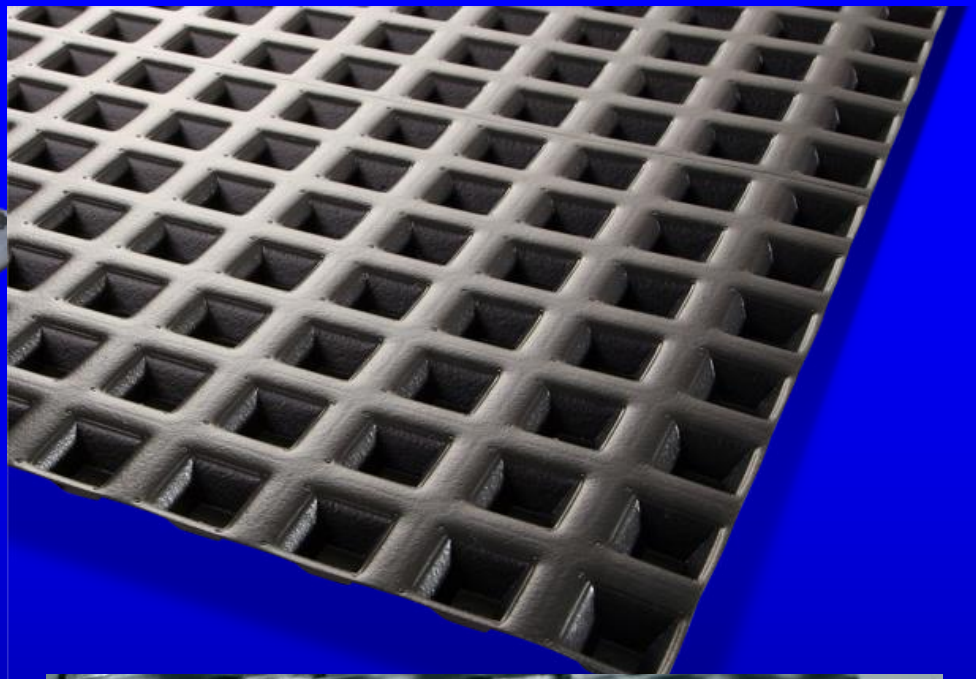


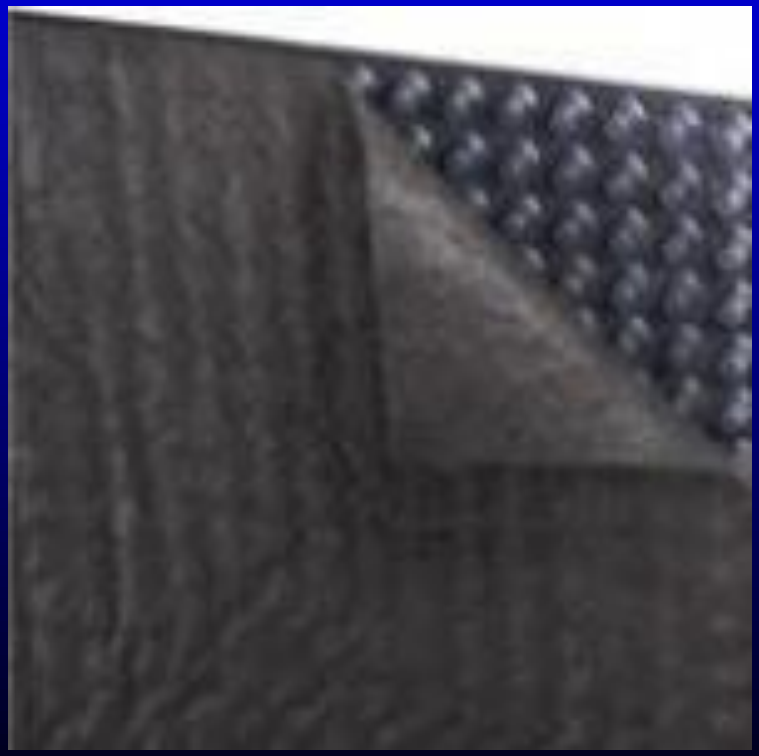
Primary Composite Liner

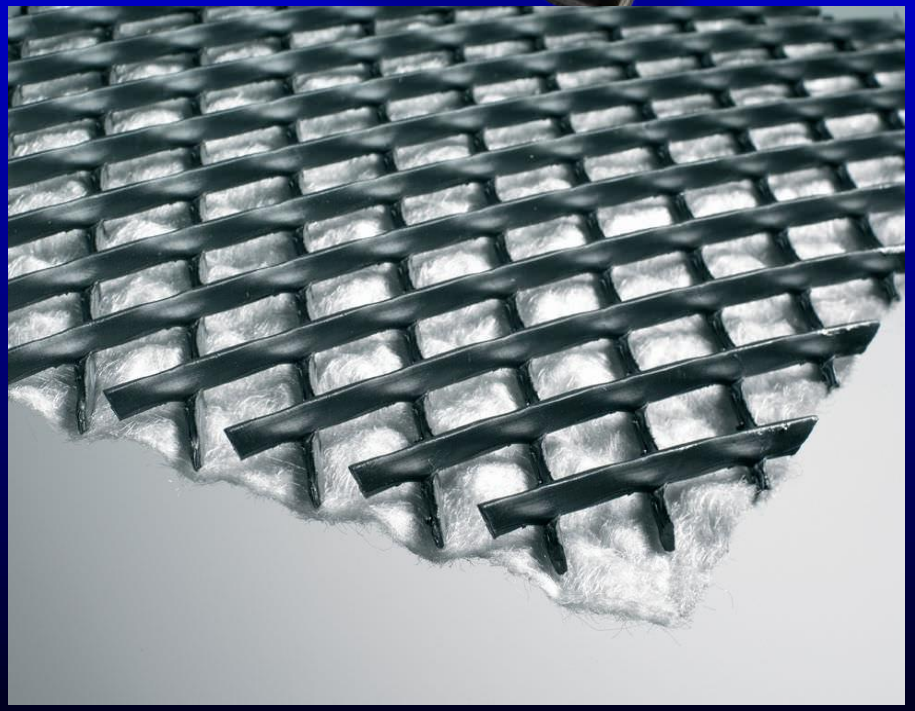
Secondary Composite Liner

Max Outflow = 30 mm/y (1 x 10^9 m/s)



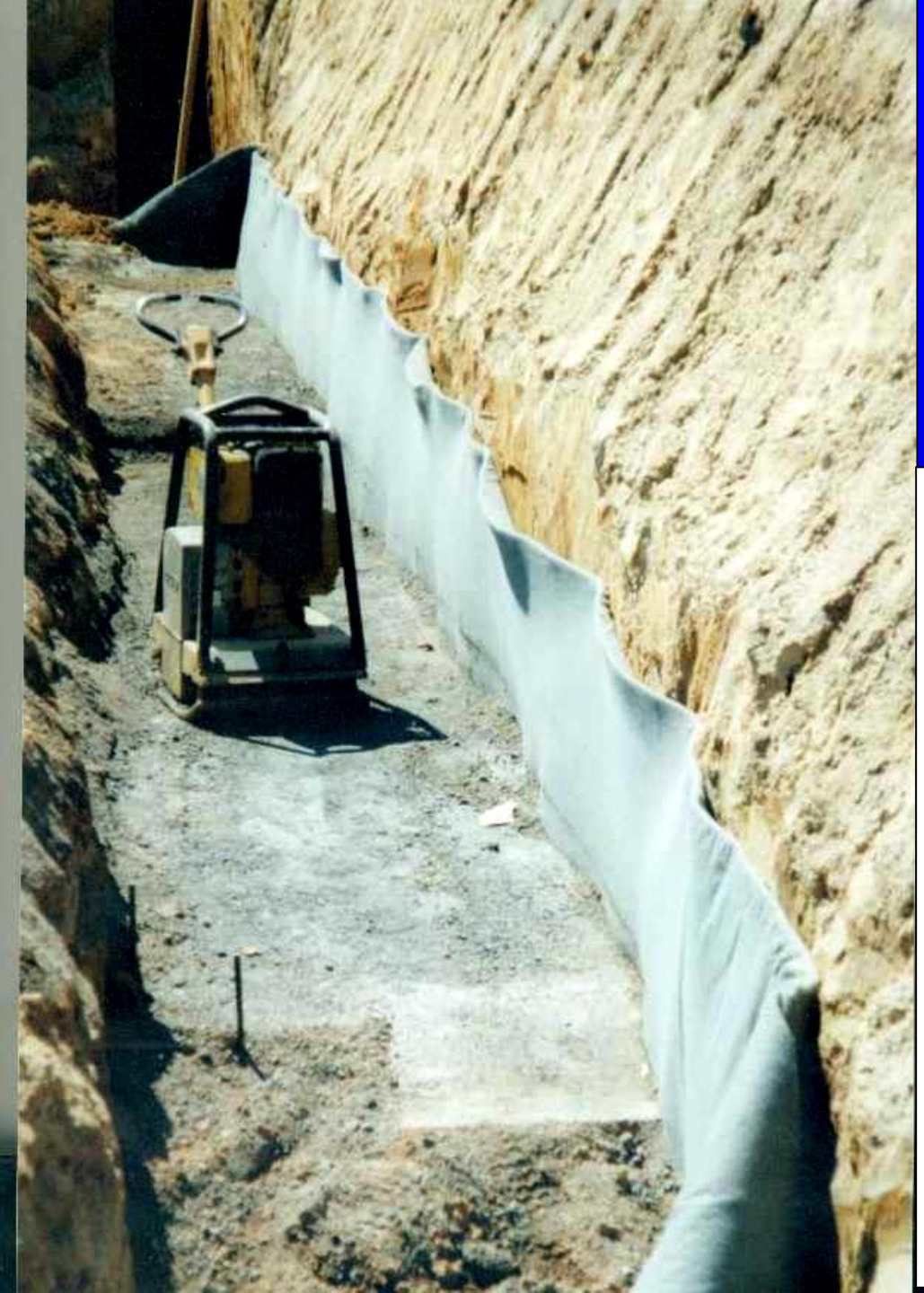






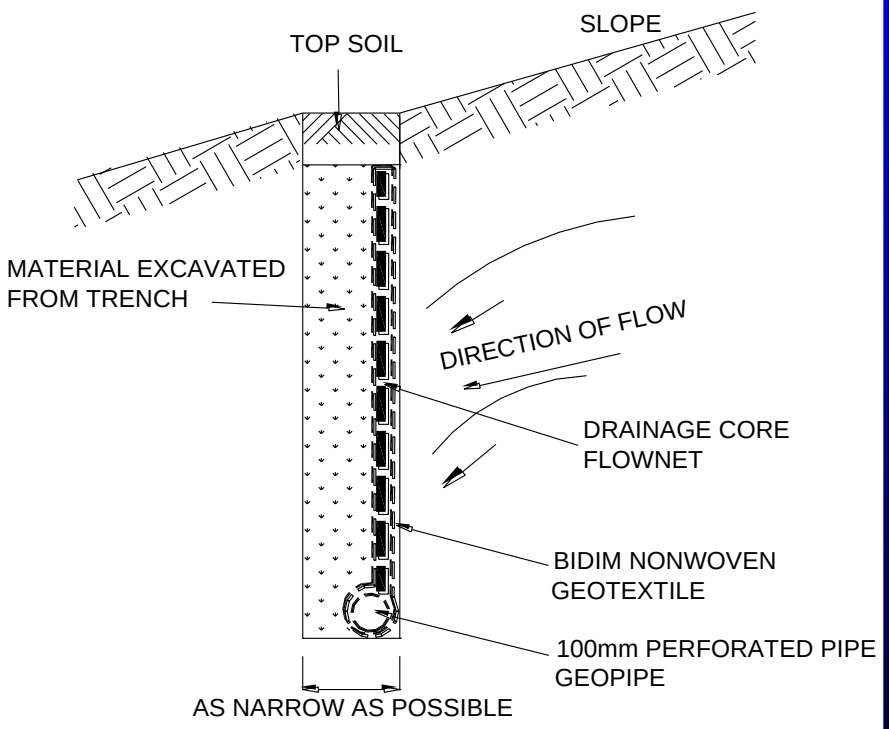
Geocomposites

- **Findrains**
- **Wickdrains / band drains**



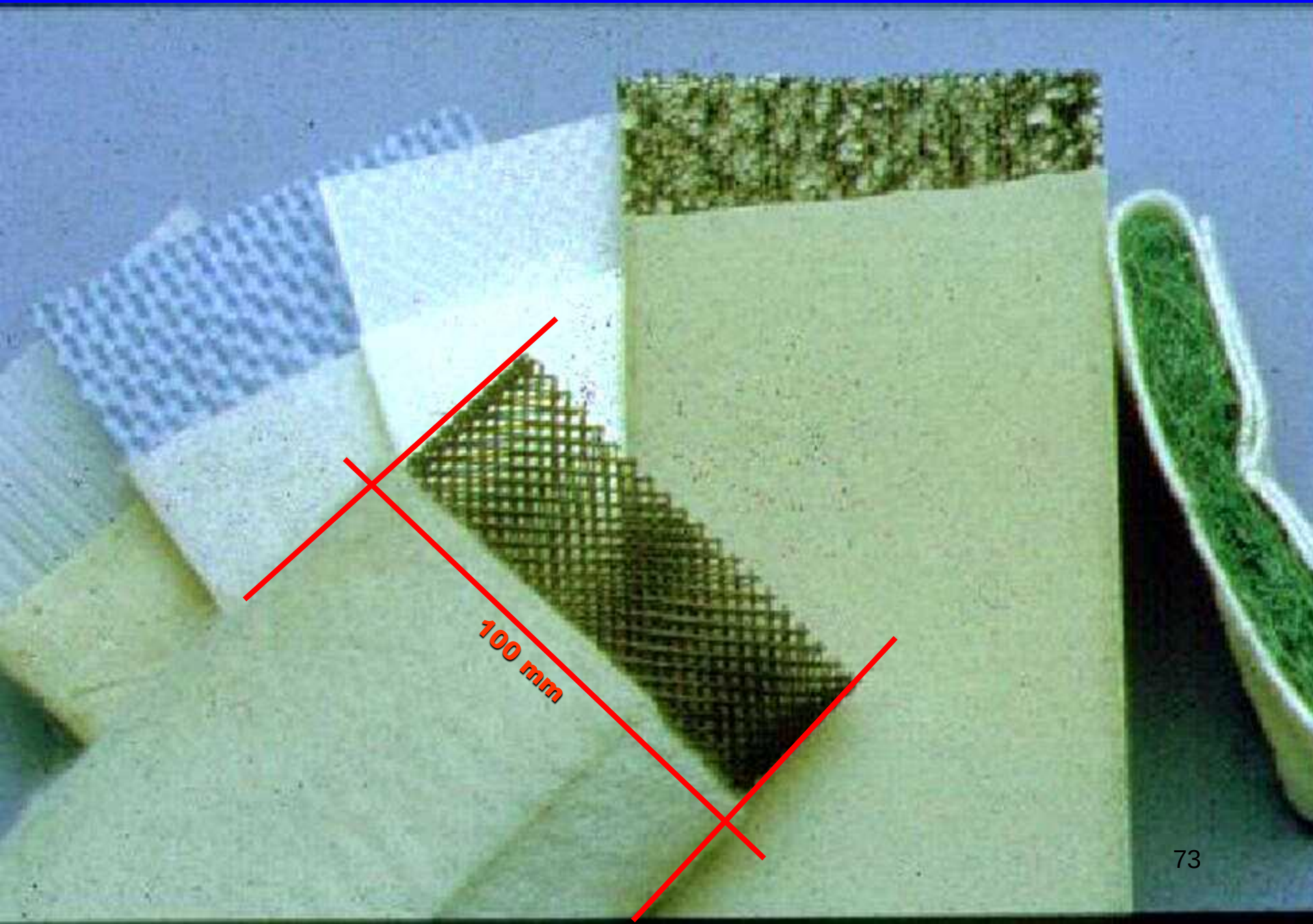
Findrains

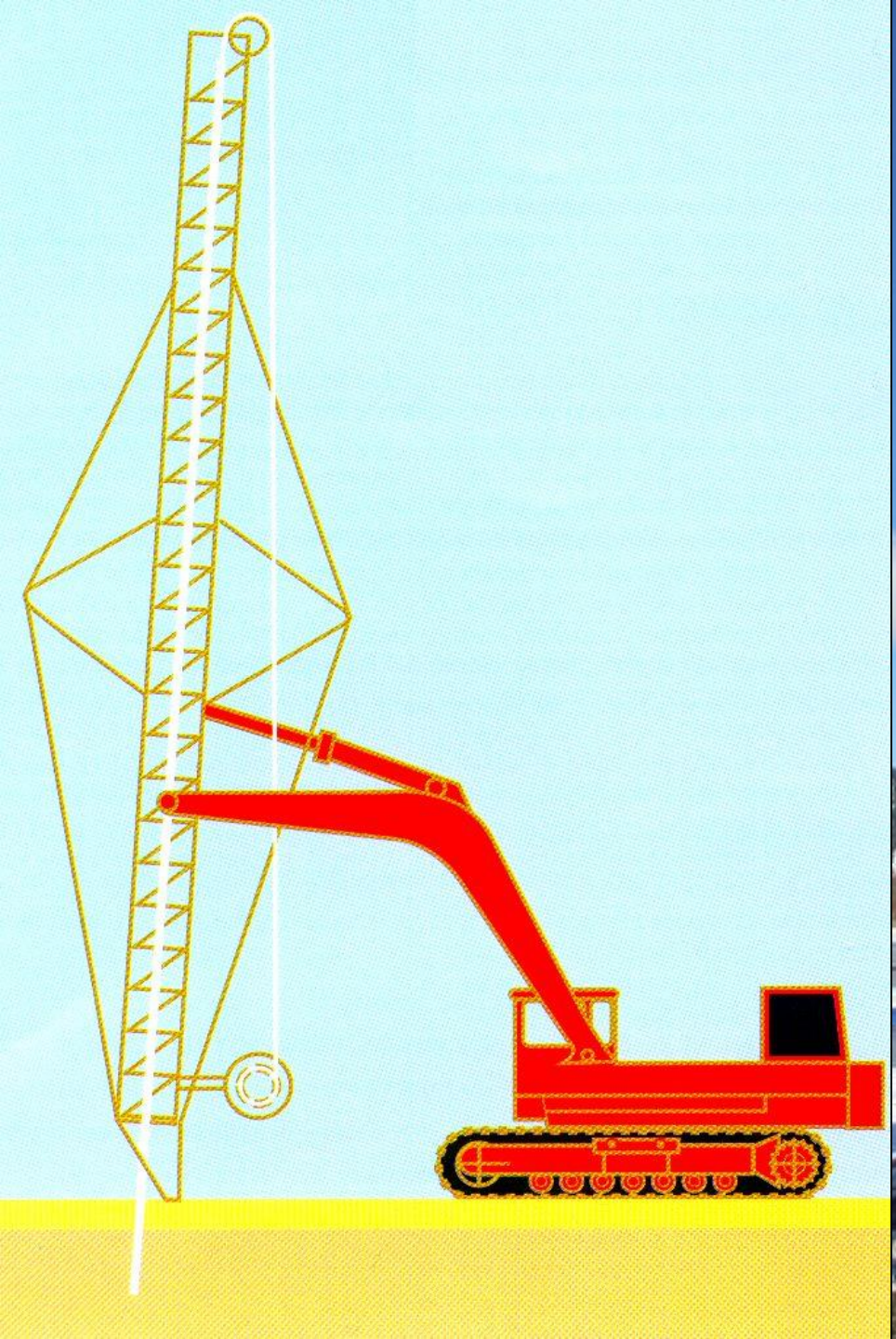
Cut-off drain



SLOPE CUT-OFF DRAIN USING EXCAVATED MATERIAL

Many Different Kinds Of Premanufactured Band Drains



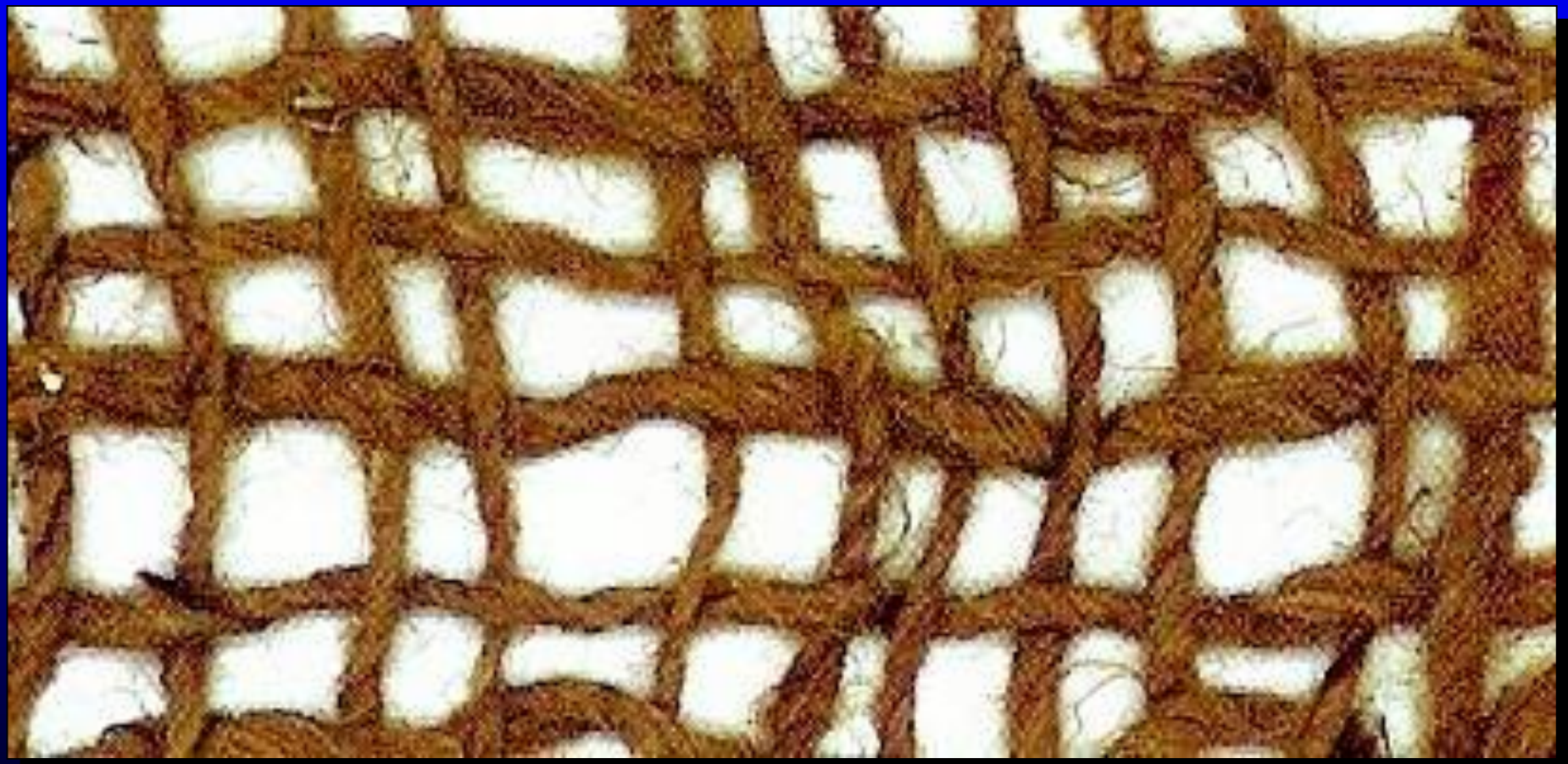



CAT

Erosion Control

- Jute nets
- Erosion control blankets
- Silt fences

Jute / Sisal nets

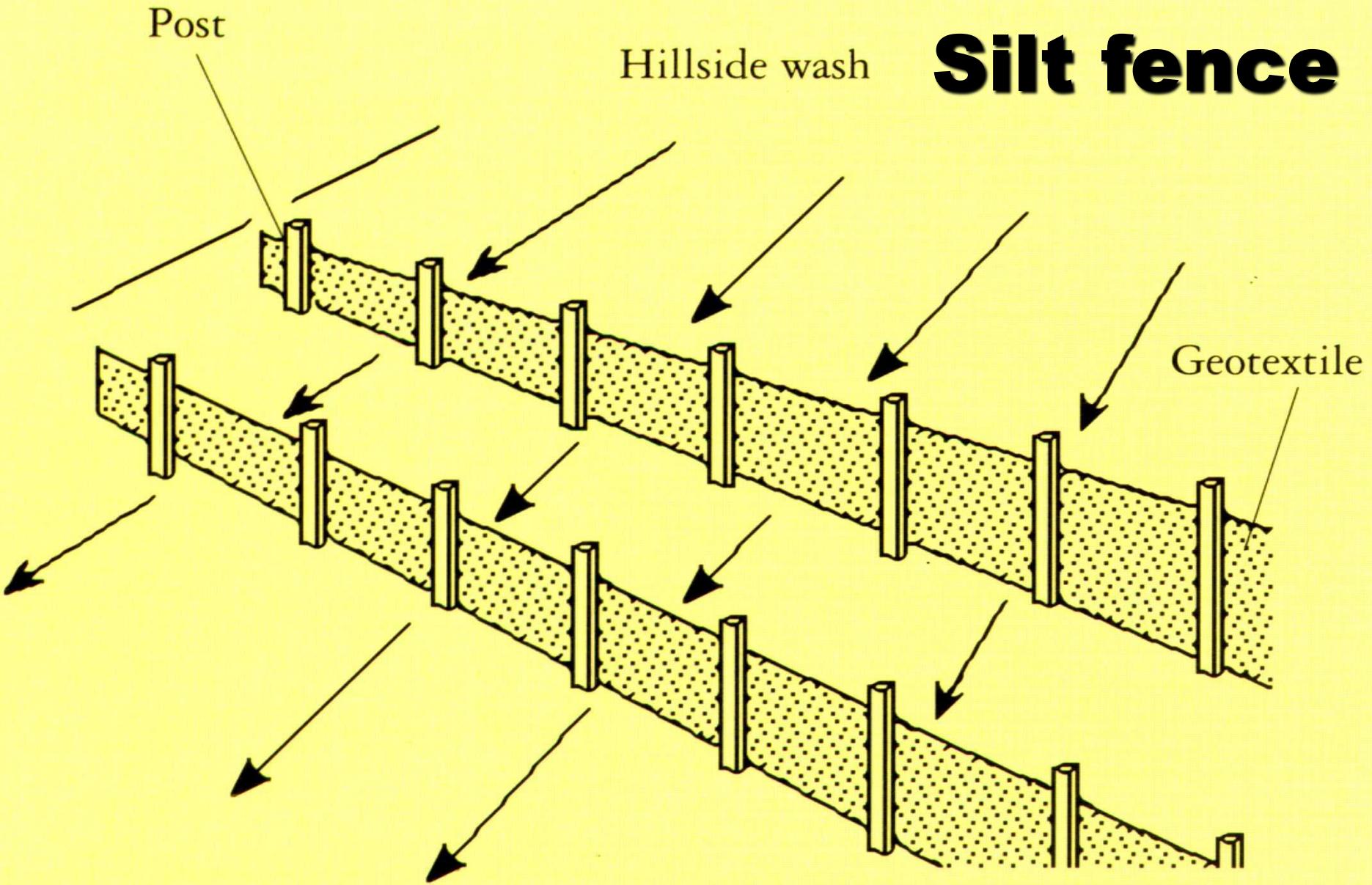






Biodegradeble
blankets

Silt fence



Benefits of Using Geosynthetics

- Savings in Materials
- Labour-Saving *or Intensive*
- Savings In Plant
- Simpler Construction
- Savings In Maintenance
- Environmental Savings