TAMPERE UNIVERSITY OF TECHNOLOGY

Clay liners: Products, Functions, Applications and Quality

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Clay liner – compacted or geosynthetic?

Compacted clay liner

Geosynthetic clay liner

Clay liner – compacted or geosynthetic?

Compacted clay liner

+ Local aggregate can be used
+ Thick; provides sorption and attenuation capacity

- Mixed and built on site – time consuming
- Pre-testing and quality control during construction required

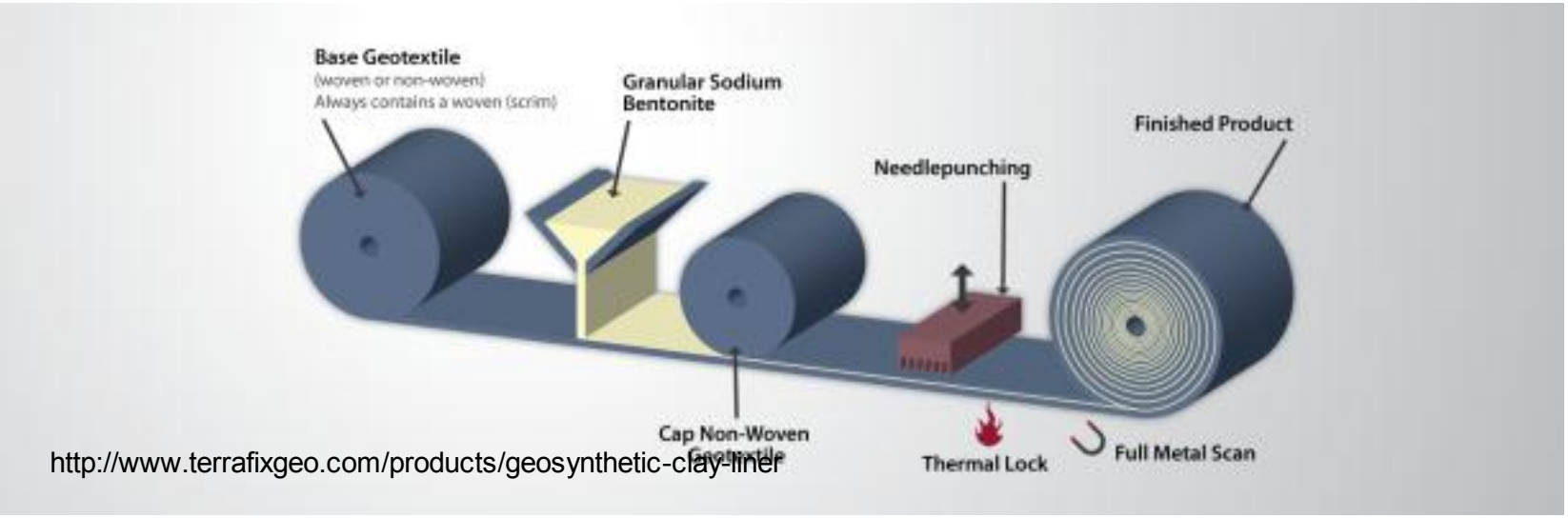
Geosynthetic clay liner

+ Produced in factory
+ Quality of raw materials and product tested during production
+ Ease of installation, also on slopes
+ Tolerates small settlements

- Imported / Transported
- Thin (can be a benefit too)

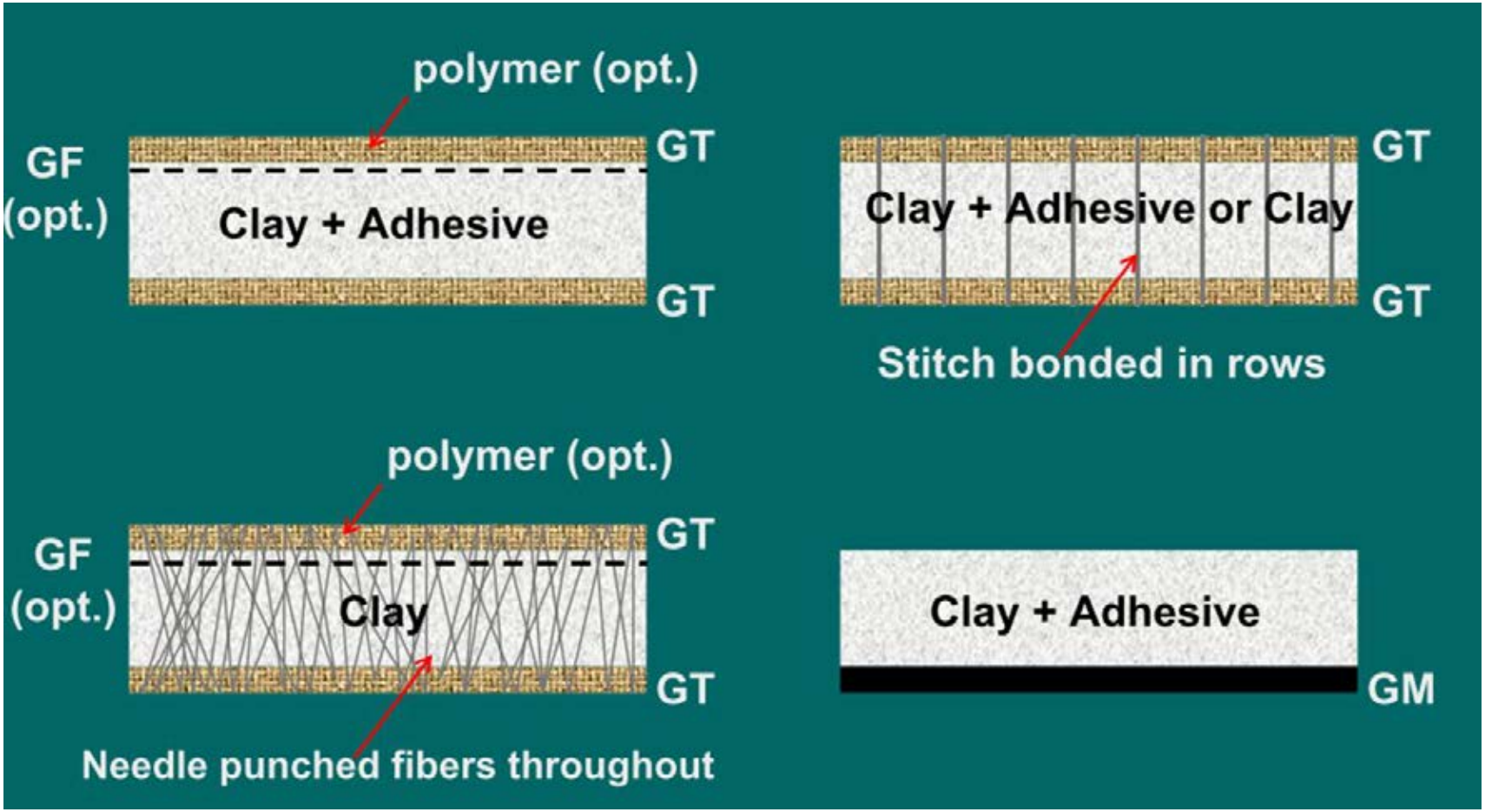
Geosynthetic Clay Liner aka Clay Geosynthetic Barrier GBR-C

- Typically a thin layer of bentonite power between two geotextiles
- Bentonite can be granular or powder (Na/Ca/Activated)
- The geotextiles can be woven or nonwovenpolymer
- Also coated geotextiles, and geomembrane/geofilm related types



http://www.terrafixgeo.com/products/geosynthetic-clay-liner

GCL Products



www.geosynthetic-institute.org/grispecs/gcl3pp.pdf.

GCL Functions

- Impermeability / encapsulation
  - Watertight (low permeability, $k \sim x \cdot 10^{-11}$ m/s)
  - Gastight (if saturated)
  - (Cat)ion exchange capacity and sorption capacity
- Protection
  - Puncture stength / mass & thickness

GCL Applications

- Ground water protection: roads, railways, chemical storage areas, waste treatment areas etc.
- Landfill cappings
- Mine tailings
- Ponds for strom water, waste liquids etc.
- Water pressure walls
- Etc.

Standard family

- *EN 13361 Geosynthetic barriers – Characteristics required for use in the construction of reservoirs and dams.*
- *EN 13362 Geosynthetic Barriers – Characteristics required for use in the construction of canals*
- *EN 13491 Geosynthetic barriers – Characteristics required for use as a fluid barrier in the construction of tunnels and underground structures.*
- *EN 13492 Geosynthetic barriers – Characteristics required for use in the construction of liquid waste disposal sites, transfer stations or secondary containment*
- *EN 13493 Geosynthetic barriers – Characteristics required for use in the construction of solid waste storage and disposal sites.*

Table 1 from EN 13492:2013 (E)

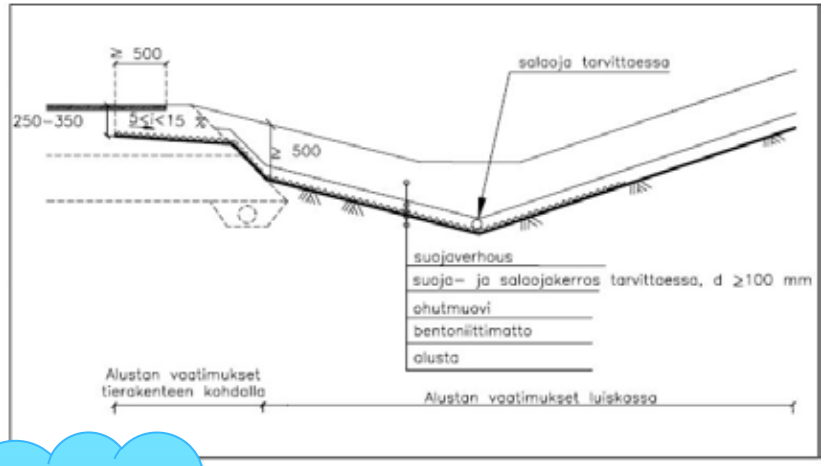
Table 1 — Geosynthetic Barriers used in the construction of liquid waste disposal sites, transfer stations and secondary containment - Functions, function-related characteristics and test methods to be used

		Geosynthetic barrier			Test methods			Remarks
Nr	**Property to be tested**	**GBR-P**	**GBR-B**	**GBR-C**	**GBR-P**	**GBR-B**	**GBR-C**	
	Physical properties							
1	Thickness	A	A	A	EN 1849-2	EN 1849-1	EN ISO 9863-1	
2	Mass per unit area	A	A	A	EN 1849-2	EN 1849-1	EN 14196	
	Hydraulic properties							
3	Water permeability (liquid tightness)	H	H	H	EN 14150	EN 14150	EN 16416	Report index flux for GBR-C.
4	Gas permeability (gas tightness)	H	H	S	ASTM D1434	ASTM D1434	EN ISO 10773	See 4.4.10.
5	Swell index	-	-	A	-	-	ASTM D5890	
	Mechanical properties							
6	Tensile strength	H	H	H	EN ISO 527-1, EN ISO 527-3, EN ISO 527-4 or EN 12311-2	EN 12311-1	EN ISO 10319	For non-reinforced GBR-P use EN ISO 527-1 and EN ISO 527-3:1995, test specimen type 5 at a speed of 100 mm/min. For reinforced GBR-P use EN ISO 527-1 and EN ISO 527-4:1997, specimen type 2 with width 50 mm, at a speed of 5 mm/min. EN 12311-2 should only be used for non-polyolefinic GBR-P. Report in all cases the maximum strength measured according to the test method.
7	Elongation	A	A	A	EN ISO 527-1, EN ISO 527-3, EN ISO 527-4 or EN 12311-2	EN 12311-1	EN ISO 10319	For non-reinforced GBR-P use EN ISO 527-1 and EN ISO 527-3:1995, test specimen type 5 at a speed of 100 mm/min. For reinforced GBR-P use EN ISO 527-1 and EN ISO 527-4:1997, specimen type 2, width 50 mm, at a speed of 5 mm/min. Calculation of elongation as defined in EN ISO 527-1:2012, 10.2, using grip separation measurement. EN 12311-2 should only be used for non-polyolefinic GBR-P.

Table 1 from EN 13492:2013 (E)

		Geosynthetic barrier			Test methods			Remarks
Nr	**Property to be tested**	**GBR-P**	**GBR-B**	**GBR-C**	**GBR-P**	**GBR-B**	**GBR-C**	
8	Static puncture	H	H	H	EN ISO 12236	EN ISO 12236	EN ISO 12236	
9	Burst strength	S	S	S	EN 14151	EN 14151	EN 14151	This test applies to GBR-C only if they contain a polymeric or bituminous barrier element.
10	Tear strength	S	S	-	ISO 34-1	EN 12310-1	-	For GBR-P use ISO 34-1:2010, Method B, angle specimen (Figure 2) without nick at a speed of 50 mm/min.
11	Friction direct shear	S	S	S	EN ISO 12957-1	EN ISO 12957-1	EN ISO 12957-1	
12	Friction inclined plane	S	S	S	EN ISO 12957-2	EN ISO 12957-2	EN ISO 12957-2	
	Thermal properties							
13	Low temp behaviour (flexure)	S	S	-	EN 495-5	EN 1109	-	
14	Thermal expansion	A	A	-	ASTM D696	-	-	
	Durability and chemical resistance							
15	Weathering	H	H	-	EN 12224	EN 12224	EN 12224	GBR-C: see 4.4.6
16	Micro organisms	A	A	A	EN 12225	EN 12225	EN 12225	
17	Oxidation	H	H	H	EN 14575	EN 14575	EN ISO 13438	For the geotextile elements and reinforcement yarns of GBR-C barriers, EN ISO 13438 is applicable.

Roadside protection



Freezing – thawing: drying - wetting

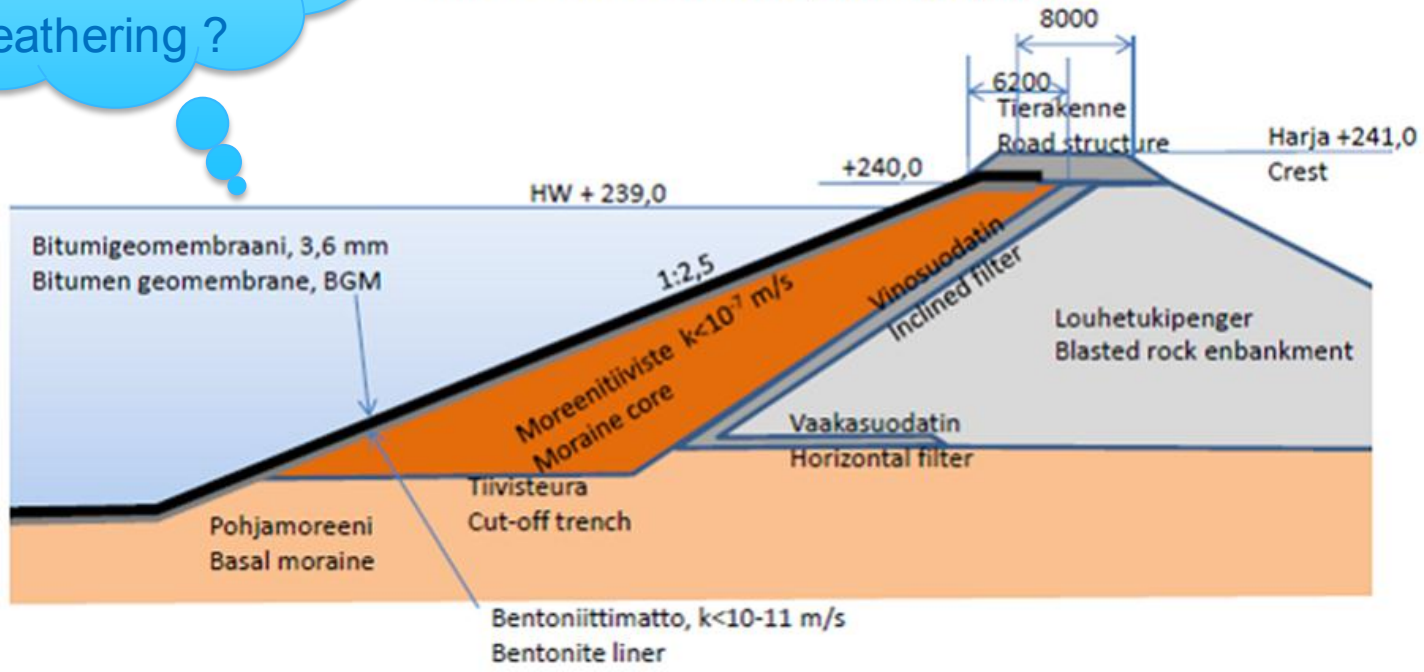
Landfill capping

Chemical compability?

Internal stability and friction

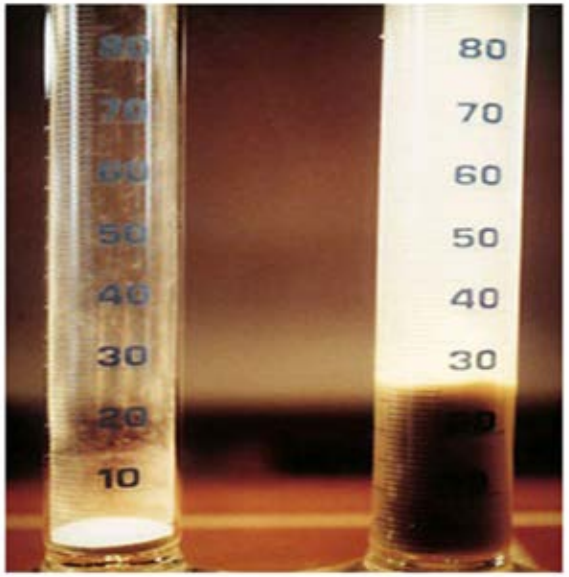
Mine tailings

Long term behaviour, chemical weathering ?



Kevitsa mining

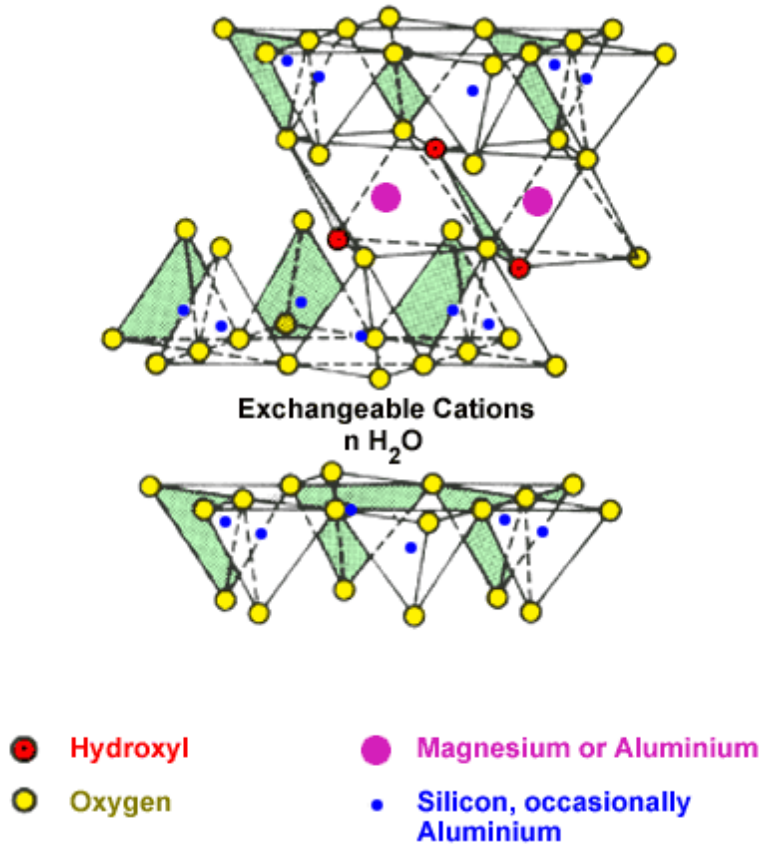
GCL Quality



- Quality of the raw materials
  - Bentonite
  - Geotextiles → resin + production
- Quality of the product
- Site specific parameters
- Quality of installation

Bentonite

- a distinct type of fine-grained clay soil typically containing not less than 80% montmorillonite clay, usually characterized by high swelling upon wetting



Finnish quidelines for landfill Quality of the bentonite

Taulukko 2. Bentoniittimatossa käytettävän bentoniitin tuotetiedot ja valmistuksen aikainen laadunvalvonta

Ominaisuus	Parametri	Menetelmä	Vaatimus	Testaustiheys
montmorilloniittipitoisuus	mineraalien määrä	XRD	80 %	joka erästä / 5000 t
	metyleenisinikulutus	VDG P 69	> 300 mg/g	
paisumiskyky	paisumisindeksi	ASTM D5890	≥ 24 ml/2 g	1/50 t
nestehukka (fluid loss)		ASTM D5891	≤ 18 ml (30 min)	1 /250 t
vedenpidätyskyky	veden adsorptio	DIN 18132 (24 h, Enslin Neff)	≥ 600 %	1 /50 t
kationinvaihtokyky (CEC)		ISO 11260	70 meq/100g	joka erästä
kalsiumpitoisuus		esim. ISO 11260	< 5 %	joka erästä

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	240	240	240	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	100	n/a	n/a	100	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) (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) (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 (7) (% 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(8)	n/a	n/a	GM Spec(8)	yearly
geofilm/polymer treated(7) (% 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) Value represents the minimum percent strength retained from the as-manufactured value after oven aging at 60°C for 50 days

(8) 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

	OMINAISUUS	TESTAUS-MENETELMÄ	VAADITTAVA ARVO	V, J, T	HUOMAUTUS
1	Läpäisevä vesimäärä	ASTM D 5887-95	(ka. 5 kokeesta) < $7x10^{-9}$ $(m^3/m^2)/s$ = $6{,}05x10^{-4}$ $m^3/m^2/vrk$ eli < 0,025 $l/m^2/h$, yksitt. maksimiarvo < $1{,}4x10^{-8}$ $(m^3/m^2)/s$ eli < 0,050 $l/m^2/h$	V, T2	35 kPa maanpaine 15 kPa vesipaine
2	Paksuus paisutettuna	EN 964-1		V	35 kPa maanpaine
3	Veden läpäisevyys		Lasketaan em. perusteella	V	
4	Leveys, rullan koko	EN ISO 10320	Valmistaja ilmoittaa	J	
5	Bentoniittimassa / m^2 ilman liima-ainetta, w = 0 %	prEN 14196	≥ 3600 g/m^2 (hajontaluku 10 %), T1 ≥ 3800 g/m^2 ≥ 3700 g/m^2 (hajontaluku 20 %) T1 ≥ 4200 g/m^2	J/5 000 m^2, T1	
6	Paisumisindeksi montmorilloniitille	ASTM D 5890	≥ 24 ml/ 2 g	J/50 000 kg, T1	Homogeeninen sakka/väri koko korkeudelta
7	Bentoniitin laatu	VDG P 69	Luonnon natriumbentoniittia, MB (metyleenisiniarvo) > 300 mg/g, montmorilloniittipitoisuus > 75 % (röntgendiffraktio)	V, J/200 000 kg	Jatkuvassa valvonnassa MB, röntgendiffraktio tai adsorptio
8	Adsorptio, bentoniitille	DIN 18132	≥ 500 % (24 h)	J/200 000 kg, T2	Ks. ominaisuus 7
9	Orgaaniset aineet bentoniitissa	Bentoniitissa ei saa käyttää paisumista lisääviä tai vedenläpäisevyyttä pienentäviä orgaanisia lisäaineita		V	Valmistajan vakuutus
10	Pintakankaiden tehokas huokoskoko O_{90}	EN ISO 12956	< 0,2 mm	V	Testataan kankaista
11	Pintakankaiden massa	EN 965 tai prEN 14196 Annex A	Kuitukangas > 200 g/m^2, Kudottu kangas > 100 g/m^2	J	Testataan kankaista
12	Sauman rakenne ja toiminta	Valmistajan ilmoittama	Muuta mattoa vastaava läpäisy	V	Valmistajan ilmoittama limityksen rakenne
13	Vetolujuus, matolle	EN ISO 10319	≥ 9 kN/m	V	Kone- ja poikkisuunnassa erikseen
14	Muodonmuutos maks. luj. kohdalla, matolle	EN ISO 10319	5 % < ε < 50 %	V	Kone- ja poikkisuunnassa erikseen
15	Repäisylujuus / peel test, matolle	EN ISO 10319	100 mm:n siirtymäalueen keskiarvotulos ≥ 60 N/ 100 mm 1)	V, J/200 000 m^2, T2	Koekappaleen tukikankaat vedetään erilleen / auki
16	Sisäiset kitkaominaisuudet, matolle	prEN ISO 12957-1 ja -2	Valmistajan ilmoittama arvo	V	Raportoidaan rakeisuus, vesipit. ja norm.jännitys
17	Staattinen puhkaisulujuus, matolle	EN ISO 12236	≥ 1,5 kN	V	
18	Jäätymis-sulamis-syklien kestävyys	prEN 14418	Kokeen jälkeen > 75 % alkuperäisestä yksittäisestä vedenläpäisevyys-, lujuus- ja venymätuloksesta	V	
19	Kuivumis-kastumis-syklien kestävyys	prEN 14417	Valmistaja ilmoittaa	V	

Finnish requirements for road side protection

Quality control on site

Sampling on site

In laboratory, typically only testing of mass of bentonite

Storing

Installation base and conditions

Location, inclination, maximum grain size, evenness…

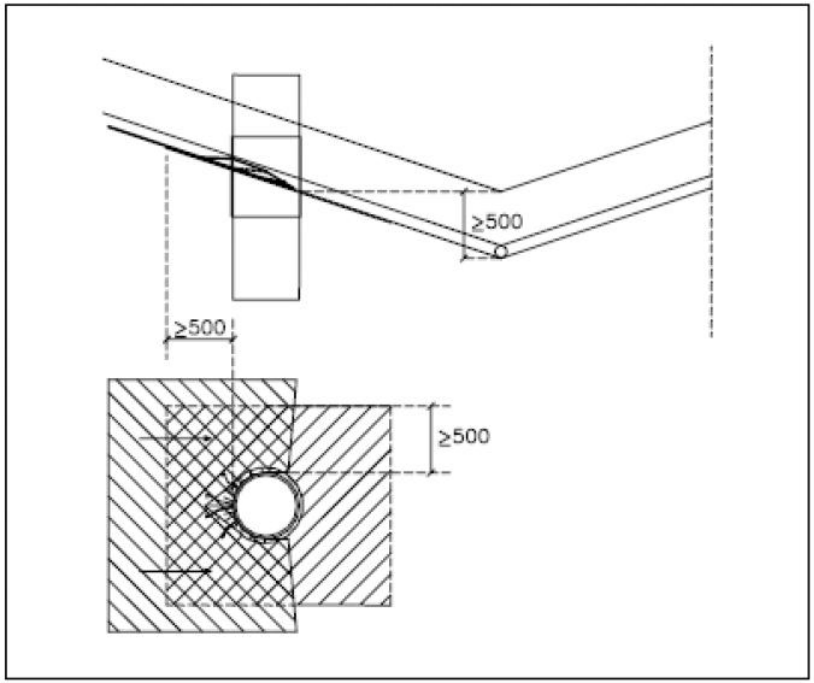
Protection

Wetting and swelling, wind and movements

Maximum grain size

Traffic load

Details



Bentonite powder, bentonite paste, overlapping

Reasons for failure / misfunction

- Mistakes in installation; wrinkles, too small overlapping, shinkage
- Inadequate cover and protection layer
- Too steep slope
- Erosion
- Affect of other materials / freezing-thawing, deccification

Proposal

- Sertification for
  - Road side protection
  - Landfill capping (both slopes < 1:3 and flatter areas)
  - Clean water ponds
- Education for installers
  - Certicate?
  - Including the safety issues

Thank you for your attention!