Material Comparisons

Geomembranes

Property	Elastoseal EPDM	HDPE	LLDPE	CSPE reinforc.	PVC	PP-R reinforc.	PP	GCL
Water Tightness	A	A	A	A	A	A	A	B
UV resistance	A	B	D	A	D	A	A	NS
Service life	A	B	C	A	D	A	A	B
Cold temperature impact	A	C	B	B	D	B	B	NS
High temperature resistance	A	B	D	B	D	A	A	NS
Flexibility	A	D	B	C	B	C	B	D
Elasticity	A	D	D	C	D	D	C	NA
Tensile strength	C	A	B	A	C	A	B	D
Chemical resistance	B	A	B	B	C	B	B	C
Resistance to hydrocarbons	D	B	C	D	C	C	C	D
Stress crack resistance	A	D	B	A	B	A	A	NA
Yield point	A	D	C	B	C	B	B	NA
Plasticiser content	A	A	A	A	D	A	A	NA
Root resistance	A	A	A	B	B	A	A	D
Rest, to microbiological attack	A	A	A	A	C	A	A	B
Puncture resistance	B	C	B	B	B	B	B	C
Surface friction	A	D	D	B	B	B	B	B
Slope stability	A	C	B	B	A	B	B	D
Thermal stability	A	C	B	A	C	A	B	A
Dimensional stability	A	D	D	A	B	A	B	A
Multiaxial strain	A	D	C	C	B	C	B	D
Resistance to settlements	A	C	B	C	A	C	B	D
Seamability	A	C	B	B	B	A	B	C
Seamability at cold temp.	A	D	D	B	D	B	A	NS
Seam strength	A	A	A	A	B	A	A	D
Seam testing	A	A	A	B	A	B	A	NA
Ease of installation	A	C	C	B	A	B	B	A
Permeability	B	A	B	B	C	B	B	B
Environmental properties	A	A	A	B	D	A	A	A
Repairability	B	C	B	D	C	B	B	NA
Details, design and installation	B	D	C	B	B	C	B	C
Conformance to substrate	A	D	C	B	B	C	B	B

A=Excellent	B=Good	C=Fair	D=Poor	NS=Not Stated	NA=Not Applicable

*) A GCL is not a geomembrane, but a natural sodium bentonite clay between two geotextiles, properly hydrated under soil cover (Confining stress)

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Material Comparisons

Comparative properties for Barrier applications

Vulcanized Elastoseal EPDM Geomembrane and HDPE Geomembrane

Thermal expansion/contraction

HDPE has a high coefficient of thermal movements and is a rigid type of membrane during moderate to high temperature differentials, such as from day to night, winter to summer. Increased outdoor temperature will cause waves in the liner due to expansion and stress due to contraction. Such continual flexing cause problems, which could lead to stress cracking and that the liner is pulled out of anchoring trenches. It also cause a major splicing problem on site and could cause site splice quality problems.

EPDM is extremely flexible, will not when used as a geomembrane have any of above problems.

Stress cracking

Stress cracking is a brittle fracture phenomenon. It is a fundamental property of crystalline HDPE and can occur at stresses that are only 30-40 % of the yield stress.

Stress cracking occurs primarily at the seams of HDPE, at stress concentrations and thickness irregularities. Thickness irregularities can be caused by thickness variations in membrane, by scratches, abrasions or grinding and at overlaps or cap strips.

EPDM is a stable, elastic product, which can be stressed and elongated two dimensional at any time during its lifetime without cracking for above reasons.

UV – resistance

HDPE have a restricted natural UV resistance. By adding 2-3 % carbon black UV-resistance is improved.

EPDM have by nature a high content (1/3 by weight) of carbon black, which always give excellent UV-resistance.

Seam strength

Welding HDPE is a sensitive, precise operation, and there is a very narrow heat range available for the welding. This heat window varies within the sheet, with outdoor temperature and variations in equipment. Therefore control of seams, check systems and skill of labours are critical for membrane performance.

EPDM are spliced with thermal welding methods giving reliable results independent of outdoor temperature or material variations. The seams are as elastic as the membrane and can easily be tested for continuity and mechanical strength by non destructive and destructive methods.

Rigidity

HDPE sheets exhibit a high degree of rigidity in both cold and warm temperatures. This make proper installation difficult, especially corners, pipe boots, flashings, overflows and penetration details. The attempt to use a rigid material in a flexible application result in basic design, engineering and installation problems.

EPDM is not only flexible at any temperature, but also elastic, will retain its length and shape after elongation. The membrane will adopt to any shape, substrate or movement with large stress forces.

Yield point

HDPE have a significant yield point, the material will flow uncontrollable at its weakest point when under stress. The yield point occurs at elongations of only 10-20 %, despite the fact that the membrane can have elongation at break as high as 700 %.

EPDM have no yield point, will always elongate up to its break elongation of approx. 400 %.

Installation

HDPE is produced in a standard size roll, size can be 7 m x 100 m, as an example. This roll can not be folded and waste during installation is significant. Heavy equipment can be needed for positioning and unrolling.

EPDM can be prefabricated to panels of 800-1500 sqm:s, each panel with measures to fit exactly into the excavation of the reservoir, and the flexible membrane can easily be transported and positioned on site, by small work crews.

Site seaming

HDPE have a coefficient of expansion of approx. 0,18 % per degree Celsius. The membrane is stiff and therefore this expansion creates wrinkles when loose laid before splicing. For example: a 100 meter long HDPE membrane is loose laid in the morning with a temperature of +10° C and spliced midday when the membrane have reached a temperature of +80° C.

The HDPE membrane have increased in length by almost 1,3 meter and the entire length differance occurs as wrinkles in the edge. Besides providing a poor appearence, this results in severe stresses in the region between the exposed membrane and the membrane that is below the liquid level, which expands very little. This high liner expansion places limitations on when seaming can be done.

EPDM does not create wrinkles since the membrane has a low coefficient of expansion and is an extremely flexible product.

Material Comparisons

Friction angle

Increased landfill capacity can be realized by taking advantage of the higher friction angles provided by EPDM. When the volumetric difference is multiplied by an average compacting factor and then multiplied by the aniticipated dumping charge per cubic meter, the increased revenue this will generate will save substantial amounts.

HDPE have a typical friction angle of approx. 16-18 degree.

EPDM have, due to its structured surface, a typical friction angle of approx. 24-27 degree. This gives the designer the possibility to design a construction with rather high slope surroundings to create a reservoir or similar that can contain a higher volume on the same land surface.

Splicing performance and speed

HDPE has a tendency to variate in thickness on membranes delivered. This creates problems to find the correct splice speed and energy consumption since the splicing method consists from melting the two splice edges together. The installer can not on site adjust these parameters and the splice result is questionable.

EPDM is vulcanised or thermal welded. The splices have the same elasticity and flexibility as the membrane itself. Thickness variations are of no importance when using this splicing methods.

Substrates

HDPE demands high compaction and a smooth and flat surface due to its rigidity, thermal expansion and the risk for stress cracking.

EPDM is a fully elastic membrane with exceptional good properties for irregular surfaces. The membrane conform to any irregularity and movements and settlements in the underground over the years does not cause problems.

Comparison of EPDM vis a vi HDPE

Typical properties

Measurements		
	HDPE	EPDM
Thickness, most frequent	1,50 mm	1,00 mm
0,80 mm	not used	available
1,00 mm	available	available
1,20 mm	available	available
1,50 mm	available	available
2,00 mm	available	available but not used
2,50 mm	available	not used
Rollwidth	5 - 10 m	1,7 m (1,3 - 3,0 m)
Rolllength	50-200 m	20-125 m
Prefabricated to specified size	No	Yes, max. 1500 sqm;s

Physical properties		
	HDPE	EPDM
Density	0,94 (Will float on water)	1,15
Tensile strength at break	30,0 Mpa	10,0 Mpa
Elongation at break	700 %	400 %
Tensile strength, yield point	0,5 Mpa	no yield point
Elongation, yield point	15 %	no yield point
Thermal movements	significant	ignorable
Low temperatue brittleness, ASTM D746	- 20°C	- 50°C
Carbon black content	2 - 3 %	35 - 40 %
Environmental Stress Crack Resistance, ASTM D 5397	200 (Value of time to failure under load of 30 % yield stress of membrane)	Not exposed to stress crack (Non polar material)

Material Comparisons

Comparison of EPDM vis-à-vis HDPE Geomembrane

Chemical resistance		
1=resistant 2=moderatly 3=nonresistant		
	HDPE	EPDM
Hydrocarbons	2	3
Anorganic salts	1	1
Animal oils	1	1
Bases	1	1
Organic salts	1	1
Vegetable oils	1	1
Weak anorganic acids	1	1
Alcoholes	1	1
Aldehydes	1	1
Amines	1	1
Esters	2	1
Ketones	3	1
Organic acids	2	1
Ethers	3	2
Phenoles	2	2
Mineral oils	1	3

Installation and splicing		
	HDPE	EPDM
Splicing - type	Fusion or extrusion	Fusion
Splicing - quality standard	Difficult operation, sensitive to external factors, weather and temperature	Uncomplicated operation sensitive only to wet weather
Membrane character	Rigid, unflexible	Flexible, conform to irregular shapes
Effective permanent elongation installed on site	3 - 8 %	50 - 75 %
Effective puncture resistance	Restricted (Crystalline material, can only absorb stress in one direction)	Excellent (Absorb substantial irregularities in substrate)
Repairbility	Restricted	Fair
Effect of high temperatures (Exposed black surfaces reach 80°-100°C under the sun in hot climates)	Severe loss of physical properties	No significant change of physical properties

Other characteristics		
	HDPE	EPDM
Price indication - membrane (HDPE 1,5 mm - EPDM 1,0 mm)	100 %	150 %
Price indication - installed lining (HDPE 1,5 mm - EPDM 1,0 mm)	100 %	125-130 %

Material Comparisons

Comparative properties for barrier applications

Vulcanised Elastoseal EPDM Geomembrane and PVC Geomembrane

Durability and UV resistance

EPDM is a synthetic rubber material that is a stable elastic product designed for decades of outdoor exposure to the elements and inert to the effects of buried environments containing microorganisms. The high carbon black content of 35-40 % guarantees UV weatherability beyond the normal life of many containments requiring exposed membranes.

PVC contains plasticizers, normally phthalates such as DEHP and Di-butyl phthalates, for flexibility. The plasticizers will diffuse and evaporate from the membrane over time, depending on the compound quality of the PVC, but the process is always ongoing. When the plasticizer is consumed the membrane will revert, during a short time interval, to a brittle, hard product with poor mechanical properties and with a total loss of elongation. PVC is sensitive to heat, sunlight and microorganisms and only buried applications can be recommended.

Organic compounds in contact with PVC can result in microbiological degradation of the membrane and there is a risk of migration when in contact with other plastic materials and concrete.

Due to the loss of plastcizers PVC is also exposed to weight loss and shrinkage over time.

Substrates

EPDM is a fully elastic membrane with exceptional elongation properties for irregular surfaces. The membrane conforms to any irregularity and movements or settlements in the subgrade even after years of service.

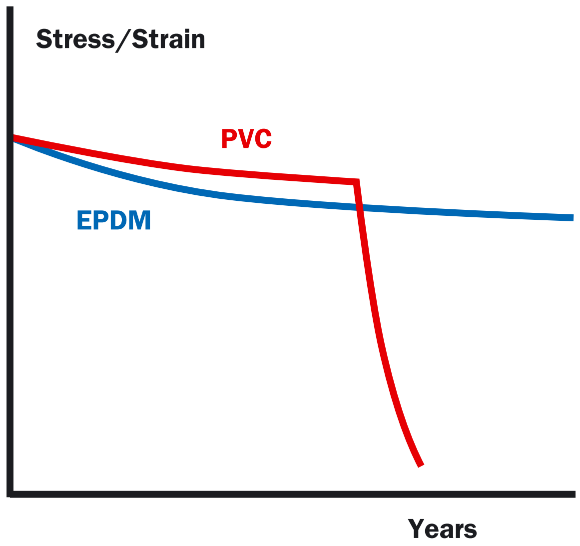
Unreinforced PVC in thickness 0,50 - 1,00 mm is very susceptible to puncture due to rocks, sharp stones or rough substrates. PVC membranes must be protected with geotextiles or protective soil layers for guaranteed long time performance.

Interface friction angle

EPDM membranes with a textured surface have a typical friction angle of 24-27 degrees with most soil types. This gives the designer the possibility to design a construction with steeper slopes or to create a reservoir or capping that can contain a higher volume on the same land surface. Increased water storage or landfill capacity can realized. Increased slopes provides increased capacity that will generate more revenue.

PVC on the other hand has a smooth surface with low surface friction. Typical interface friction angles are approx. 16-18 degrees and the risk of slippage of cover soils and slope stability must be considered by designers.

Stress/Strain properties of EPDM and PVC membranes after long periods of aging



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Material Comparisons

Low temperature environments

EPDM is not affected by low temperature extremes, even if exposed. It remains flexible and can be installed and seamed at below freezing temperatures. Low temperature resistance is to -50° C, thus applications in extreme northern climates is acceptable.

PVC has a limited resistance to low temperatures. The membrane will become stiff and brittle, with increased susceptibility to tear and puncture. The best quality PVC can have a brittle point of -25°C, but in most cases the effective low temperature resistance is restricted to -17° C.

Cost effectivness and compatibility with Landscaping designs

EPDM provides a cost effective product and system. Panels are prefabricated to between 800 and 1500 sqm:s, with custom sizes to fit exactly into the excavation of the reservoir. The flexible membrane can easily be transported and positioned on site, by small working crews. Installation of single panel projects, up to 2000 sqm:s in size, can be made by owner or general building/excavating contractor.

PVC is prefabricated to large panels with similar methods, but 0,75-1,00 mm PVC is not as durable and resistant to installation stress, will not take as much abuse from rough installation surfaces. In addition protection from environmental degradation will require a minimum 50 cm of soil cover. EPDM can be installed exposed to the atmosphere and will not be damaged by placement of landscaping rock directly on the membrane.

The Environmental concern

EPDM membranes are environmentally friendly, chemically stable and contain no dangerous additives or plasticizers which could be released.

EPDM can be recycled, by grinding and reusing the elastomeric components, which can then be mixed into new EPDM rubber compounds.

PVC is a chlorinated product containing UV stabilizers and plasticizers. In summary, PVC is regarded as an environmental problem because:

- Chlor organic chemicals are generally dangerous for our environment. They cause "green house" effects, they destroy the ozone layer in the atmosphere, they are cancerous, they have caused poisoning by PCB and they are not broken down by the nature. The production of PVC raw materials are regarded as environmentally questionable. PVC contains phthalates, plasticizers which is proven to be cancerous. PVC can cause dioxin damages and some contains heavy metals. Also chlorinated aromatic hydrocarbons, which is dangerous for human health.

Material Comparisons

Comparative properties for barrier applications

Vulcanized Elastoseal EPDM Geomembrane and Geosynthetic Clay Liner (GCL)

Durability and Aging

EPDM is a synthetic rubber material that is a stable elastic product designed for decades of outdoor exposure to the elements and inert to the effects of buried environments containing microorganisms. The high carbon black content of 35 – 40 % guarantees UV weatherability beyond the normal life of many containments requiring exposed membranes.

GCĹs are not designed nor intended for exposed conditions. In fact, a GCL must be installed carefully on a firm, stable substrate and must be provided with a 1,0 m minimum cover to establish required confining stress during the bentonite hydration process. Without proper installation with requisite compacted soil, a GCL will not provide a long term barrier to fluid migration.

Low Temperature Environments

EPDM is not affected by low temperature extremes, even if exposed. It remains flexible and can be installed and seamed at below freezing temperatures. Low temperature resistance is to - 50° C, thus applications in extreme northern climates is acceptable.

GCĹs have been used in extreme northern climates, however they must be installed and covered above 0° C ambient due to the stiffness at cold temperatures and the bentonite moisture content (freezing). Again, due to the bentonite component, GCĹs are susceptible to low temperature brittelness, especially at the seam areas. The GCL must be buried below the frost depth which could be over 1,5 m in northern climates.

Thougness, Conformability and Effectivness

EPDM has a working strain to over 400 % and conforms readily to placement of overburden materials and installation over rough substrates without puncture. The rubber surface texture provides excellent friction resistance to prevent soil sliding on the surface as well as superior adherence to the subsoils (outstanding lay flat characteristics). As an elastic material, EPDM will retain its length and shape after elongation and thus will adapt to any shape or substrate movement (localized subsidence) without rupture.

A GCL, on the other hand, has no working strain as bentonite has no tensile strength. GCĹs must be placed and hydrated under load (cover soils unit weight). Once in place, a GCL can not be subjected to movement as in settlements or local subsidence as this will cause cracking and destroy the barrier function. GCL seam areas are overlaps only with no mechanical strength. Soil movements and subsidence as in a landfill will cause the seam area to separate again destroying the barrier function.

Interface Friction Considerations with Soil and Slope Stability

EPDM, due to its rough texture surface, inherent soft rubber surface properties and surface conformability provides a high interface friction angle when tested against a varity of soils. Friction angles in the range of 25 to 30 degress are not uncommon. Thus, steeper covered slopes are possible with EPDM.

GCĹs also have initial high surface friction characteristics with soils. However, once the GCL bentonite is fully hydrated under load and on a slope, stability of the slope cover soils is dependent on the stitch bonding which holds the two geotextile layers in a GCL together (hydrated bentonite has very low shear strength). Over time and under stress, the stitch bonding will creep resulting in pullout of the fibres and slope failure. Thus slopes with GCĹs should be limited to 1V : 5H (11 degrees) or less.

Installation and Field Seaming

EPDM is supplied in large prefabricated panels that lay flat with little or no wrinkles. The panels up to 1500 sq.meters in size can be custom fabricated to fit the shape of the installation reducing waste. Seaming can be accomplished very easily and quickly by the contractor using conventional thermal welding methods with little or no restriction as to installation temperature (a big advantage for northern cold climates). The seams are easily tested for continuity and mechanical strength by non destructive and destructive methods.

GCĹs can be supplied only in large rolls up to 5 m in width with no possibility for custom panel fabrication. Seams are not mechanically attached and provide no tensile strength. The seam area overlap is “sealed” by spreading bentonite by hand or spreader. The placement method is dependent on hand labor and can result in highly variable amounts of bentonite or missed areas with no bentonite. There is no method for field testing the seam effectiveness.

Material Comparisons

Attachment to Structures

EPDM is easily bonded to concrete, wood and block using either solvent or waterbased adhesive systems. The EPDM rubber surface texture conforms readily to the rough concrete surface allowing intimate bonding contact as well as ease of mechanical attachment by conventional methods.

GCL´s do not conform to surfaces such as concrete due to its stiff surface fabric texture and can not be permanently adhered to these sufaces with adhesives or mechanical attachment methods.

Field Repair Procedures

EPDM is easily repaired by conventional thermal seaming or by using tape seam patches even after many years of service in an exposed application.

A GCL can only be repaired by placing a loose patch with bentonite and only prior to placing the required cover soil. A GCL can not be repaired once it is hydrated and in fact hydration of the GCL prior to placement of cover soils will require removal of the GCL.

Compatibility with Adjacent Materials and Environments

EPDM, due to its rubber properties and toughness, is not affected by the placement on or under materials such as large stone or block and can be placed with fresh concrete. Aquatic plants and root systems do not penetrate EPDM and water quality of a pond or reservoir is not affected.

GCL´s must be placed on smooth compacted substrates. Cover soils must be free of large stone and debris. Root systems will penetrate the nonwoven geotextile layer of a GCL, thus compromising the barrier function. The compatibility of the bentonite with contained or migrating fluids must be carefully considered and tested as the bentonite may not hydrate properly as in an aqueous environment.

Seaming Comparison

EPDM is easily seamed in the factory or field using conventional thermal fusion welders and is independent of temperature and material variations. Once thermally welded, the seams are as strong as the parent material with full tensile strength and elasticity. Large factory panels reduce the amount of field seams required.

GCL rolls are only overlapped and provided with a "bead" of dry bentonite to form a seal once hydrated under load. These seams are approximately every 5 m resulting in a large quantity of labor intensive field seams. These seam areas, however, have no tensile strength and will separate easily during construction (espacially on slopes) and due to soil movement (settlements) after placement.

Summary

A GCL is by definition not a geomembrane. Geomembranes, like EPDM, is designed for complete watertightness, a GCL will always allow water to penetrate. In fact GCL´s were developed to replace a compacted clay liner (CCL) as a secondary barrier to a primary geomembrane and thus should always be used in association with a geomembrane system where required. However, GCL´s are also beeing marketed as isolation barriers in projects that should be restricted to geomembranes.

GCL´s are a relatively new type of product, with little practical experience, espacially the textile technique. GCL´s found its first use at the end of the 80-es. Rubber based geomembranes, first with the polymer butyl and later, form the early 70-es, with EPDM, have been used since the 1940-es.

GCL´s must be based on sodium bentonite, which swells more than calcium bentonite under load.

The installation of GCL´s present a large technical problem and must often be regarded as un-controlable. The product may not be exposed to cold temperatures or moisture before placement and coverage. The substrate must be 100 % smooth, i.e. a 4 mm sharp stone is not acceptable. The GCL roll must be covered with soil the same day it is positioned, otherwise the hydration process will start without load, the product must be replaced and scrapped. If the GCL become dry it will shrink and crack. When re-hydrated the GCL will return to its original function as a barrier, but the cracks will remain.

EPDM membranes can be installed at any time of the year, even in cold climates, and the installation quality can be secured and documented.

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Material Comparisons

Design Consideration and Ultimate Performance		
	Barrier Material	
	EPDM	**GCL**
Resistance to sunlight (UV)	4	1
Resistance to Cracking (all causes)	4	2
Resistance to heat (hot, Arid Climate)	4	1
Resistance to Chemical Environment	4	2
Ease of Panel Installation	3	4
Field Seam Quality	4	2
Repairability	3	0
Ease of Attachment to Structures and Pipes	4	1
Low Temperature Installation	4	1
Conformance to all Substrates	4	3
Resistance to Rupture due to Puncture	3	2
General Lay Flat Characteristics	4	3
Resistance to Installation Damage	3	3
Resistance to Installation Wrinkles	4	3
Resistance to Soil Slippage (Surface friction)	4	4
Resistance to Soil Movement (Settlements)	4	1
Design Strain – All Directions (Multiaxial)	4	1
Long Term Slope Stability	3	1
Overall Long Term Durability	4	3
Overall comparative rating	**3,7**	**2,0**
Ratings		
4=Excellent; 3=Good; 2=Fair; 1=Poor; 0=not possible/not applicable		

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