Rationale for the GRI-GM34 Specification on EIA (PVC + KEE) Geomembranes

George R. Koerner and Jamie Roth Koerner

Abstract The Geosynthetic Research Institute (GRI) test method GM34 "Test Methods, Test Properties and Testing Frequency for Ethylene Interpolymer Alloy (EIA = PVC + KEE) Geomembranes" sets forth a set of minimum properties that must be met, or exceeded upon manufacture. In the context of quality systems and management, this specification is targeted toward manufacturing quality control (MQC). The properties listed in this specification were obtained by testing multiple commercially available products according to the latest standard test methods established by either the American Society of Testing and Materials (ASTM) or the Geosynthetic Research Institute (GRI). The unique aspect of this specification is the requirement for long-term performance testing of the geomembranes. Three different endurance tests are specifically designated to challenge the longevity-weathering-aging of the EIA geomembrane. This paper describes the rationale of selecting the relevant test methods and the background for establishing the specified values. Also presented in this paper is the frequency required when performing the various tests.

Keywords Ethylene interpolymer alloy · Geomembrane · Specification · Physical · Mechanical · Chemical · Hydraulic and endurance properties

1 Introduction

EIA geomembranes have been used as liquid and gas barriers in geoenvironmental applications for more than 40 years. The only *generic* specification available to aid engineers was published in 1983 by the National Sanitation Foundation (NSF) as Standard No. 54. The standard provided a list of tests together with their corresponding minimum values. Although four revisions were carried out in the intervening years, the standard was still lagging behind the state-of-practice of the EIA geomembrane industry. Most importantly, the long-term performance of the material

G. R. Koerner · J. R. Koerner (✉)
Geosynthetic Institute, 475 Kedron Avenue, Folsom, PA 19033, USA
e-mail: Jamie@geosynthetic-institute.org

H. Jeon (ed.), *Proceedings of the 2nd International Conference on Geosynthetics and Environmental Engineering*, Lecture Notes in Civil Engineering 396,
https://doi.org/10.1007/978-981-97-7766-2_22

was never properly addressed. For a number of interrelated issues, NSF decided to withdraw from the geosynthetic industry by terminating the publication of Standard No. 54 at the end of 1997.

Considering the above situation, a completely new EIA specification was needed. In 1994, at the prompting of the U.S. Environmental Protection Agency, a technical task group was formed within GRI consisting of four EIA geomembrane manufacturers. The group decided that the purpose of the specification was to be directed at manufacturing quality control (MQC) only. This infers that if an owner or specifier has unique or extenuating circumstances for a particular project, modifications in the form of a project specification can be made, however, such changes should be communicated accordingly to the manufacturer.

The new EIA = PVC + KEE specification covers physical, mechanical, chemical and endurance properties of EIA geomembranes. The majority of the required properties are evaluated by test methods established by the ASTM D35 Geosynthetics Committee. In cases where no ASTM standards are available, GRI test methods were developed and are included accordingly. It should be pointed out that this specification only covers EIA geomembranes with a "polyester" scrim inclusion. It does not cover EIA geomembranes with nylon scrim, nor is it specific to the scrim properties or geometry.

The GRI-GM34 specification covers EIA geomembranes with four different thicknesses (0.76, 0.91, 1.13 and 1.52 mm). Table 1 is the actual specification table which includes test methods, limiting values, and testing frequencies. The respective values are presented according to three different conditions (severe (S), moderate (M) and typical (T)) based on the perceived site and environmental conditions. Such conditions are application specific and often based on surcharge conditions and deployment equipment. The minimum testing frequencies are also defined for each required property. Most of the testing frequencies are based on weight in units of kilograms. The reason for using kilograms instead of number of rolls is to achieve a consistent value between different sheet thicknesses and sheet widths. There are six notes associated with the table to further clarify the test conditions and specific requirements. The entire specification, in its latest revision, is available free on the institute's website at http://www.geosynthetic-institute.org/specs.htm

2 Discussion

Many test methods and procedures have been considered for incorporation in this specification. The rationale for including specific test methods/procedures is presented below.

Table 1 Tabular form of EIA Geomembrane Specification

System properties (composite EIA plus scrim)	Test method	Metric			Metric			Metric			Metric			Testing Frequency (minimum)
		0.76 mm			0.91 mm			1.13 mm			1.52 mm			
Thickness (min. ave.)—mils	D751	nom.			nom.			nom.			nom.			Per roll
• lowest individual of 10 values—%		−10			−10			−10			−10			
Fabric scrim type	NA	Polyester			Polyester			Polyester			Polyester			Per roll
Finished coated mass/unit area (min. ave.)	D 751	949 g/m^2			1017 g/m^2			1356 g/m^2			1899 g/m^2			Per roll
CONDITION[a]	–	S	M	T	S	M	T	S	M	T	S	M	T	–
Grab tensile properties (min. ave.)[b]	D 751													22,680 kg
• strength • elongation		890 N 20%	890 N 20%	890 N 20%	890 N 20%	890 N 20%	890 N 20%	1112 N 20%	1112 N 20%	1112 N 20%	1112 N 20%	1112 N 20%	1112 N 20%	
Trouser tear resistance (min. ave.)[b]	D 5884	156 N	133 N	111 N	245 N	222 N	200 N	267 N	245 N	222 N	289 N	267 N	245 N	22,680 kg
Hydrostatic burst (min. ave.)	D 751	2413 kPa	2068 kPa	1723 kPa	3792 kPa	3447 kPa	3102 kPa	4826 kPa	4481 kPa	4137 kPa	5516 kPa	5171 kPa	4826 kPa	22,680 kg
Puncture resistance (min. ave.)	D 4833	556 N	444 N	334 N	890 N	778 N	667 N	1223 N	1112 N	1001 N	1334 N	1223 N	1112 N	22,680 kg
Ply adhesion (min. ave.)[b]	D 6636	2.6 N/mm			2.6 N/mm			3.5 N/mm			3.5 N/mm			22,680 kg
Dimensional stability (max. ave.)[b]	D 1204	1.0%			1.0%			1.0%			1.0%			22,680 kg
EIA only properties														
IH-NMR determination of PVC and KEE content	D 8154	PVC 30% KEE 10%			PVC 30% KEE 10%			PVC 30% KEE 10%			PVC 30% KEE 10%			Per each formulation

(continued)

Table 1 (continued)

System properties (composite EIA plus scrim)	Test method	Metric	Metric	Metric	Metric	Testing Frequency (minimum)
		0.76 mm	0.91 mm	1.13 mm	1.52 mm	
Chlorinated water resistance star fold at 50 °C[d, f] Pass/fail after 90 days by GRI GM16 and ASTM D882 grab tensile properties	GRI GM24	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Per each formulation
Oven aging at 85 °C[f] Pass/fail after 90 days by GRI GM16 and ASTM D822 strip tensile properties	D 5721	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Per each formulation
UV resistance[e, f] Pass/fail after 10,000 light hours by GRI GM16 and ASTM D882 strip tensile properties	D 7238	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Pass (i.e., no cracks observed) Retained 80%	Per each formulation

[a] (S) Severe, (M) Moderate, (T) Typical
[b] Regardless of machine direction (MD) or cross machine direction (XMD)
[c] Incubated at 100 °C ± 1 °C for one hour
[d] Incubated at 50 °C ± 1 °C at 10 ppm chlorine concentration in distilled deionized water. Samples are dried and solution is changed once a week during incubation
[e] The conditions of the UV Fluorescent exposure method should be 20 h. UV cycle at 75 °C followed by 4 h. condensation at 60 °C
[f] Tested on unreinforced geomembrane specimens (EIA Only) via ASTM D882

2.1 Physical Properties

Thickness—The nominal thickness for all geomembranes is an obvious target value. This specification uses ASTM D751 to obtain an average thickness which must be greater than the nominal value; however, the lowest individual value of 10 values can be −10% due to variation of the material and testing. The test frequency for this property is to be performed on every roll of geomembrane.

Mass per unit area—The weight for all geomembranes is an easy physical check of the geomembrane. This specification uses ASTM D751 to obtain an average mass per unit area which must be greater than the minimum average value. The property is obtained by die cutting specimens across the roll width and measuring the know area's mass. The test frequency for this property is every roll of geomembrane.

Dimensional Stability—The purpose of this test is to assess the presence of residual stress in the geomembrane and its reaction to elevated temperature. The test is conducted according to ASTM D 1204 on a (254 mm × 254 mm) square specimen. The dimensional changes of the specimen are measured after incubation in a forced air oven at 100 °C for one hour. The changes should be found to be less than 1% regardless of the thickness, formulation, or type of manufacturing process. Please note that the scrim reinforcement controls dimensional stability performance and limits expansion or contraction of most EIA geomembranes. This is a hallmark of the material and leads to its exceptional intimate contact with the subgrade. The test frequency is every 22,680 kg.

2.2 Mechanical Properties

Tensile properties—The test is performed according to ASTM D 751 using rectangular (100 mm × 150 mm) grab specimens with a gauge length of 75 mm and a speed of 300 mm/min. Two test parameters are required: break strength and elongation. The minimum average value of these two parameters refers to both machine and cross machine directions with 5 test specimens being required for each direction. The minimum strength values are giving in force units and governed by the scrim not the ply break. Regarding the elongation, the minimum for thicknesses is 20%, again controlled by the nature of the scrim. The test frequency for these tensile properties is every 22,680 kg.

Tear resistance—The trouser tear test is performed according to ASTM D 5884 using rectangular (200 mm by 2000 mm) specimens with a 75 mm cut at a speed of 300 mm/min. The minimum average tear resistance is related to the thickness of the material and the nature of the scrim. Data in the table is presented in units of (N) Newton. The test frequency is every 22,680 kg.

Hydrostatic Resistance—This test is conducted according to ASTM D 751 for "Coated Fabrics". The test is designed to evaluate the burst strength of scrim reinforced geomembranes. The test is conducted over water, not a neoprene diaphragm.

The test frequency is every 22,680 kg and the pressures achieved by these materials are surprisingly high.

Puncture resistance—This value is evaluated according to ASTM D 4833. The minimum average puncture resistance is determined as the minimum average of five test specimens. Data in the table is presented in units of (N) using a 8 mm probe with a forty five degree chamfer, penetrating a specimen held in a flanged opening of 45 mm diameter. The test frequency is every 22,680 kg.

Ply Adhesion—This value is evaluated according to ASTM D 6636. The minimum average strength of the highest force recorded during the separation is the ply adhesion strength. The result is determined on 25 mm wide strip specimens as the minimum average of five test specimens. This test is best done with the cooperation of the manufacture via inserting a Teflon bond breaker in a section of geomembrane during lamination. Without the bond breaker separation, the ply is very difficult or impossible to separate. Data in the table are presented in units of "N/mm". The test frequency is every 22,680 kg.

2.3 Chemical Property

Determination of PVC and KEE content of EIA geomembranes—The test is performed according to ASTM D 8154 using Nuclear Magnetic Resonance Spectrophotometry (NMR), [1]. It is mainly used to identify and characterize the structure of organic compounds via NMR spectra. In this technique, a NMR signal is produced when a sample is placed in a magnetic field by excitation of nucleic sample with radio waves into nuclear magnetic resonance and further detected using radio sensitive receivers (Chary and Govil, 2008). This technology provides additional information related to chemical structure of the polymer. Unfortunately, this technique requires an extraction of the PVC from the KEE in an organic solvent which is not standardized. In addition, most extraction techniques are only 80% effective. None the less, the criteria for PVC and KEE in the total EIA formulation are 30% and 10% respectively.

2.4 Endurance Properties

Chlorinated water resistance—The purpose of this immersion challenge is to artificially accelerate the aging of EIA geomembrane. The specification states the resistance to oxidative degradation by chlorine solutions over a relatively short time frame and at a relatively high concentration. Increasing the free chlorine concentration in the incubation solution should result in faster degradation of the tensile properties and may lead to cracking of the material. In contrast, chlorine resistance is an indication of more stable formulations, [2]. The incubation is held at 50 °C ± 1 °C at

10 ppm chlorine concentration. The solution is verified weekly with a conductivity probe to maintain its concentration (see Figs. 1 and 2).

Oven aging—The purpose of oven aging is to challenge the long-term thermal behavior of the EIA geomembrane. The incubation procedure is conducted according to ASTM D 5721 in forced air ovens at 85 °C for 90 days, [3, 4]. A performance challenge of "no cracking" is required to ensure the durability of the geomembrane as well as the 80% retention of both strength and elongation.

Forced air oven aging takes place in a simple and consistent incubation environment, although it is recognized that such an environment does not simulate true field conditions. The temperature of the oven is elevated to 85 °C in order to shorten the testing duration. Incubated samples are retrieved and tested after 90 days via ASTM D882 strip tensile test. The percent retained value cannot be less than 80% for either

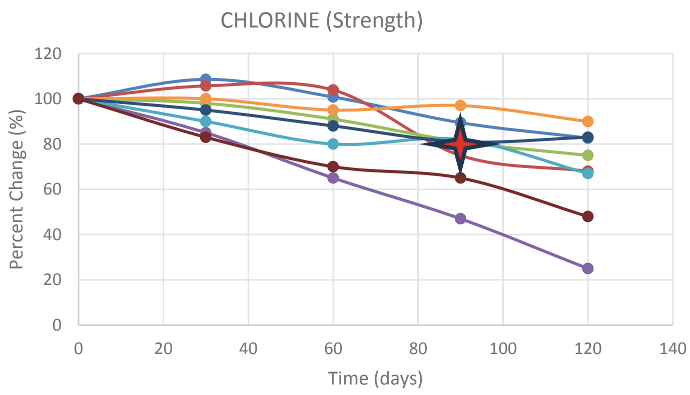

Fig. 1 Percent change versus time strength results for chlorine aging

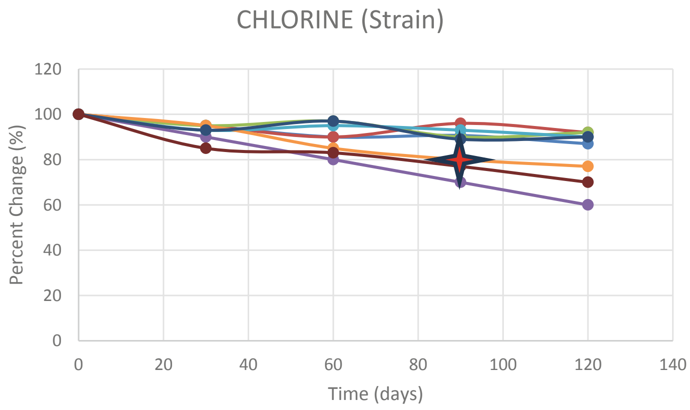

Fig. 2 Percent change versus time elongation results for chlorine aging

strength or elongation. These values are established based on data from the GRI inter-laboratory test program. Results of which are shown in Figs. 3 and 4.

Ultraviolet (UV) Resistance—This property is very important for EIA geomembranes that are exposed to sunlight during their service life. The QUVA fluorescent device was selected to simulate UV degradation of the geomembrane in the laboratory. Such devices are simple to use, small in size, require little maintenance and are relatively inexpensive to maintain and operate. The exposure procedure used to assess UV resistance is conducted according to ASTM D 7238. The exposure time is for 10,000 light hours, while alternating 20 h of UV at 75 °C followed by 4 h condensation at 60 °C.

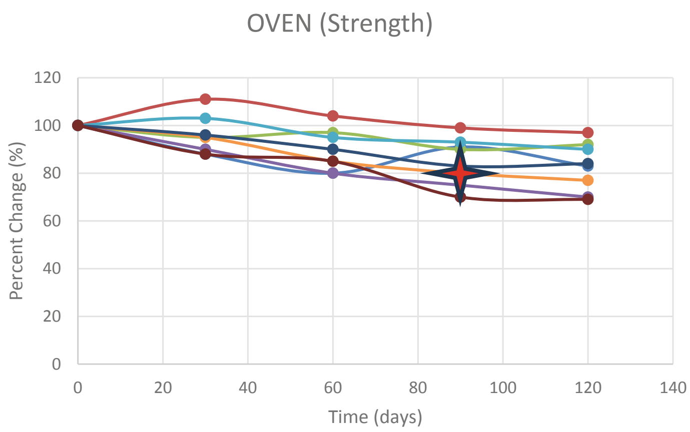

Fig. 3 Percent change versus time strength results for oven aging

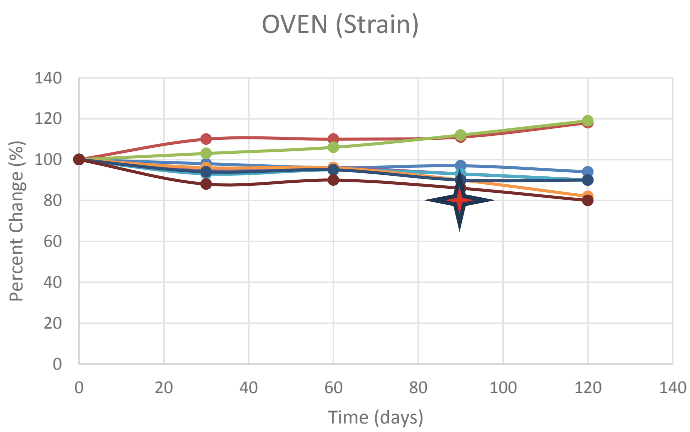

Fig. 4 Percent change versus time elongation results for oven aging

Incubated samples are retrieved after 10,000 light hours and tested via ASTM D882 strip tensile test. The percent retained value cannot be less than 80% for either strength or elongation. These values were established based on data from the GRI inter-laboratory test program, results of which are shown in Figs. 5 and 6. The test needs to be conducted on a per formulation basis.

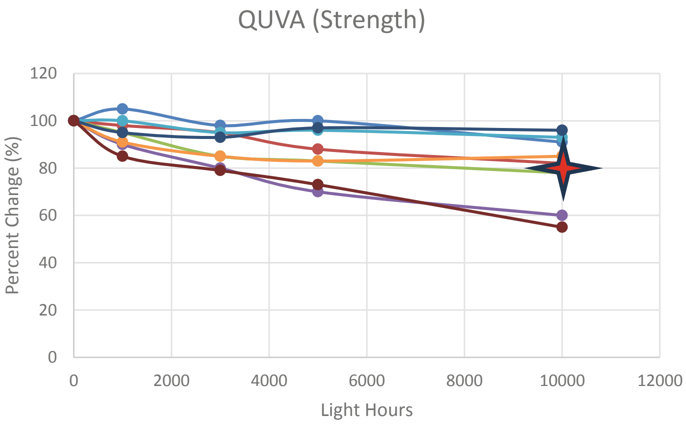

Fig. 5 Percent change in strength versus light hours of QUVA exposure aging results

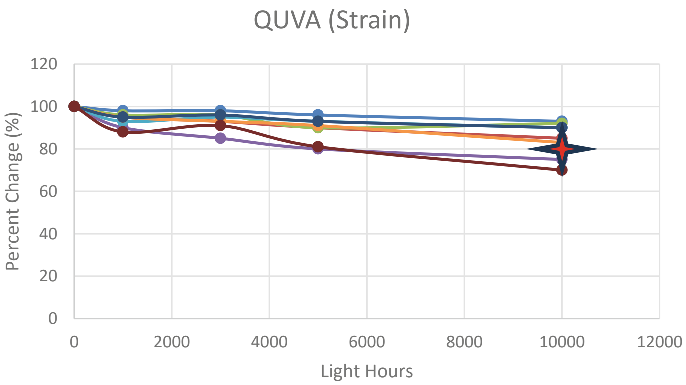

Fig. 6 Percent change in strain versus light hours of QUVA exposure aging result

3 Conclusion

EIA geomembrane (as with all geosynthetics) material modifications and upgrading by the manufacturing/resin/additive community is an ongoing process. As such, any specification must be reviewed and modified (as required) on a regular basis. GRI-GM34 requires such a review every 24-months. The information presented in this paper represents Revision 9, dated July 13, 2023 and it can be found on the Institute's website at www.geosynthetic-institute.org/specs.htm. For more information, consult the Fabricated Geomembrane Institute (FGI) "Current Overview of EIA Geomembranes" (2023). [5]

Acknowledgements This specification represents the combined efforts of the resin and geomembrane manufacturer organizations over the course of several years. The authors sincerely appreciate the participant's efforts and congratulate them in the development of this specification. Sincere appreciate is also extended to all of the GSI members, in particular owners/consultants/government agencies and test laboratories, for their review and comments.

References

1. Chary KVR, Govil G (2008) NMR in biological systems. Springer Science & Business Media, pp 113–162. ISBN 13: 9789048176984
2. Morsy MS, Kerry RR, Abdelaal FB (2020) Longevity of 12 geomembranes in chlorinated water. Can Geotech J 58(4): 455–467. https://doi.org/10.1139/cgj-2019-0520
3. Halse Y, Wie1tz J, Rigo J-M, Cazzuffi DA (1991) Chemical identification methods used to characterize polymeric geomembranes. Geomembranes identification and performance testing, report of technical committee 103-MGH. In: Rollin A, Rigo J-M (eds) Mechanical and hydraulic testing of geomembranes. RILEM. Chapman and Hall, pp 316–336
4. Thomas RW, Ancelet CR (1993) The effect of temperature, pressure, and oven aging on the high-pressure oxidative induction time of different types of stabilizers. In: Geosynthetics '93 conference proceedings, IFAI, St. Paul, MN, pp 915–924
5. Fabricated Geomembrane Institute (2023) Current overview of EIA geomembrane. University of Illinois at Urbana—Champaign, p 18