LAYFIELD GEOSYNTHETICS

TECHNICAL PAPER

Development of a High Performance Geosynthetic Drainage Net

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ABSTRACT

The Geosynthetic mining and containment sector is swiftly adapting to higher performance requirements. Emphasis is being placed on the development of products with enhanced durability, specifically designed to guard against prevalent failure modes such as environmental stress cracking, slow crack growth failures, and oxidative degradation.

In response to a request from an international mining corporation for a tailored drainage solution, we have developed a Geonet drainage composite to meet next generation performance requirements. This geocomposite is crafted using a cutting-edge resin design and formulations that amplify its resistance to both environmental stress cracking and slow crack growth failures by more than 40 times compared to the standard Geonet in the industry.

We provide data gathered that delve into the basic principles of polymers to elucidate why this material significantly surpasses the performance of existing market offerings. Furthermore, we explore the rigorous testing procedures implemented during the product's development to ensure its longevity and effectiveness, targeted to the specific operational needs of the project.

Keywords: geonet; drainage; durability; mining; acid; stress-cracking

INTRODUCTION

Geosynthetic containment, drainage, filtration and reinforcement products are often exposed to high temperatures and oxidative chemicals, particularly in mining, oil & gas, waste and wastewater industry sectors. In one such example, the authors were asked to provide comment on the suitability of geonet, geotextile and geomembrane products to be used at a mine site with aggressive environmental conditions exposed to a very acidic liquor. A current geomembrane product was identified from previous laboratory testing and a similar recent project at the site, however, it was determined that the available geonet was unlikely to meet the required design life with possible stress cracking and loss of compressive strength resulting in a substantial reduction in drainage performance. While significant data exist on drainage and flow performance of geonets, there is limited understanding of long-term durability factors. Creep resistance under compressive load, stress crack resistance, and oxidation time become critical measures of long-term durability and drainage performance over the expected lifetime. This becomes increasingly relevant for applications in hostile environments, or when exposed to aggressive liquids.

These applications include tailings dams and heap leach pads with high compressive loads and acid liquors, reactive industrial landfill cells, industrial wastewater treatment ponds, and high temperature evaporation ponds with aggressive chemicals like acids.

In this application, the drainage geonet was expected to be continuously exposed to an acidic mining liquor with an average pH of 0.8, at a liquor temperature of 16-35ºC with high concentrations of sulfates and chlorides. A minimum service life of 20 years was required. Existing geonet resins were not considered appropriate for use in this particularly aggressive application. Thus, the authors proposed a best in class solution aiming to meet the needs of this aggressive environment.

DISCUSSION

A collaborative study was undertaken by the resin and geonet manufacturers to review the suitability of different polyethylene (PE) resins used in various extrusion processes. It was quickly determined that a bimodal PE resin would provide a superior long term performance in the application in question.

2.1 Bimodal PE resins

Over the past two decades, the molecular design of high-density polyethylene (HDPE) resins has undergone significant evolution. Advances in catalyst technology and polymerization processes have enabled the development of resins with bimodal molecular weight distributions (MWD) and targeted comonomer incorporation. These innovations have led to enhanced performance in critical areas such as environmental stress cracking resistance (ESCR) and slow crack growth (SCG), without compromising the high density and mechanical properties that make HDPE ideal for geosynthetic applications.

In PE resins, the terms unimodal and bimodal refer to the shape of the molecular weight distribution curve, typically measured by gel permeation chromatography (GPC). These curves reflect the distribution of polymer chain lengths within the resin.

Unimodal PE resins exhibit a single, broad peak in their MWD (**Fig. 1,** red line). These materials have been in use since the 1950s and are valued for their ease of processing and cost-effectiveness. However, their relatively uniform comonomer distribution and lack of high molecular weight tailing can limit their resistance to stress cracking and long-term durability in demanding applications.

Bimodal PE resins, by contrast, display two distinct peaks in their MWD (**Fig. 1,** blue line), representing a blend of low and high molecular weight fractions. This dual distribution enables a unique combination of properties:

- The low molecular weight (LMW) component contributes to stiffness and processability.
- The high molecular weight (HMW) component enhances toughness, ductility, and crack resistance.

This architecture allows bimodal resins to outperform unimodal counterparts in applications requiring long-term mechanical integrity, such as geonets and other geosynthetics.

A key advantage of bimodal systems lies in the controlled placement of comonomer. In traditional unimodal resins, comonomer is typically distributed evenly across the molecular weight spectrum. However, in a two-stage polymerization process, comonomer incorporation can be concentrated in the HMW fraction. This is significant because, in most PE resins, comonomer incorporation tends to be minimal in the highest MW chains and more prevalent in the LMW region. By reversing this trend—placing comonomer into the HMW component—the final resin structure benefits from enhanced tie chain formation.

Comonomers such as 1-butene or 1-hexene introduce short-chain branches that disrupt crystalline packing, promoting the formation of tie molecules—polymer chains that span across crystalline lamellae through amorphous regions. Since cracks typically initiate and propagate through these amorphous zones, tie molecules play a critical role in retarding crack growth and improving long-term durability.

In contrast, unimodal resins, while easier to process and offering consistent properties, lack the tailored architecture of bimodal systems and may fall short in high-performance, long-lifetime applications.

Figure 1 below illustrates representative GPC curves for unimodal and bimodal PE resins. (Note: The curves are illustrative and not based on specific commercial data.)

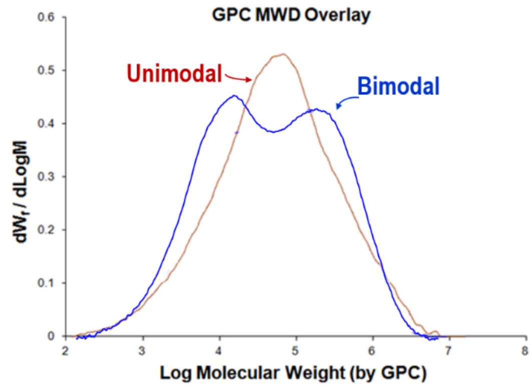

Figure 1. Molecular Weight Distribution of Bimodal & Unimodal Resins

The nuanced benefits between bimodal and unimodal resins are discussed in detail in Design Innovations of High Density Polyethylene Pipe Grade Resins2.

2.2 Resin comparison

Following a review, the manufacturer (Layfield) conducted extrusion trials to determine if geonet could be successfully manufactured from each of the potential candidate resins, and to modify production equipment if necessary. As a result, two unimodal resin samples A and B, and one bimodal resin sample C were selected for further evaluation.

The bimodal resin Sample C exhibited superior breaking strength, strain hardening modulus (SHM) and environmental stress crack resistance (ESCR). This resin was selected for further development in this geonet application.

There is a strong correlation between SHM and ESCR. The SHM is the slope of the stress-strain curve after yield has been reached as the PE material strain hardens before the ultimate tensile strength is reached. The bimodal material C exhibits a 2.5X higher SHM compared to the unimodal resins, and correspondingly an exceptional resistance to ESCR as compared to the unimodal materials A & B. A higher SHM indicates the material's ability to undergo significant plastic deformation after yielding, which is critical for dissipating energy at crack tips and delaying failure. Crack layer theory suggests the reason for this improvement. Once a crack is initiated in the wall, fibrillation occurs within the crack. These fibrils orient, elongate and strain harden prior to ductile failure. Improvements in the strain hardening behavior help stabilize the cracks and retard propagation. When there is enough fibrillation, from the improved number of tie chains, this can result in crack arrest.

Table 1. Resin Properties of Geonet Samples

Side	Method	Unit	Sample A	Sample B	Sample C
			Unimodal	Unimodal	Bimodal
Density	ASTM D1505	g/cm3	0.955	0.954	0.954
Melt Index	ASTM D1238	g/10 min	0.35	0.32	0.28
Yield Stress	ASTM D638	(MPa)	4.2	3.7	4.4
Break Strength	ASTM D638	(MPa)	10.4	10.4	21.3
Elong.at Break	ASTM D638	%	741	897	722
Strain at Break	ASTM D638	%	1552	1518	1258
Ave. SHM @ 80ºC	ISO 18488	(MPa)	13.2	12.7	34.1
ESCR Cond B	ASTM D1693	(hrs)	24	25	>1000*
NCTL	ASTM D5397	(hrs)	1.2	1.4	45.7

*Final test result pending.

Thus, when considering resin design, the resin that has the majority of the comonomer in the high molecular weight region produces a design with increased number of tie chains that work to arrest crack growth, thereby slowing down and even arresting the slow crack growth rate. It can be considered that a higher SHM means the

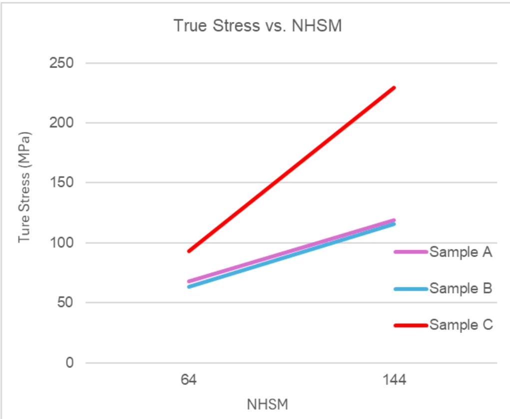

Figure 2: Strain hardening profile for unimodal PE samples A and B, and bimodal PE sample C.

polymer can better withstand the formation and propagation of cracks under stress, which is essential for applications where the material may be exposed to harsh conditions and expected to perform for a significant period of time.

The three materials were tested per ISO 18488 @ 80ºC. True Stress in MPa vs. Neo-Hookean Strain Measure (NHSM) values taken at draw ratios of 8 & 12 were plotted in **Fig. 2**.

While oxidation induction time (OIT) can be influenced by the level and type of antioxidant package present in the base resin or introduced via masterbatch—and can be tailored at the time of production—the SHM and stress crack resistance are generally direct functions of the resin's molecular design.

Although OIT is not a standalone predictor of service life, it serves as a valuable indicator of oxidative stability when used in retention studies over time, particularly under elevated temperatures and chemical exposure. This approach has been widely supported in the long-term durability research of geosynthetics, including the work of Dr. Kerry Rowe, who has demonstrated how antioxidant depletion profiles can be used to estimate service life in aggressive environments.[3]

The higher SHM and ESCR observed in the tested bimodal PE resin C clearly demonstrate its advantage over the two unimodal PE resins evaluated for this application.

2.3 Geonet properties

Further geonet manufacturing trials of resin sample C were undertaken to perform application specific testing, including compression and oxidative performance, and immersion trials in representative liquor to assess chemical resistance performance.

Geonet samples were immersed for 30 days at 19ºC and 50ºC in representative liquor in accordance with ASTM D5322-17. The test liquid (**Table 2.)** contained high concentrations of iron, aluminum, copper, manganese and potassium sulphates, chlorides, and sulfuric acid resulting in a pH1.0, consistent with the concentrations measured on site. Material properties including oxidation induction times, density and sample mass were compared before and after immersion at 19ºC and 50ºC. The samples exhibited no discernable change in properties, confirming the bimodal resin was a suitable candidate for this aggressive application. The results of this testing are presented in **Fig. 3**. It is worth noting that immersion testing was not continued on the unimodal samples as the initial results were already quite low. Although the geonet produced with Sample C performed well in testing, it was determined that a slight increase in antioxidant additive levels would enhance the product's longevity. **Table 3.** presents the test results conducted by a third-party laboratory on the final product made with Sample C.

Table 2. Immersion Test Liquid Chemistry

Element		Concentration (g/L)
Copper	($CuSO_4$)	4.66 g/L
Chloride	($CaCl_2$)	10.93 g/L
Iron (Total)	($FeSO_4$)	191 g/L
Aluminimum	($Al_2(SO_4)_3$)	110.9 g/L
Potassium	(K_2SO_4)	1.76 g/L
Manganese	($MnSO_4$)	2.92 g/L
Sulphuric Acid	(H_2SO_4)	17 g/L

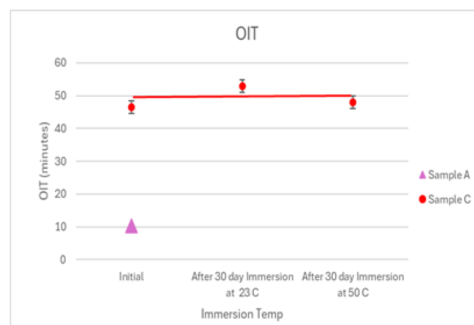

Figure 3: Oxidation Induction Time – Initial, and after immersion at 23ºC and 50ºC of bimodal sample C.

Table 3. Example bimodal Geonet Material Properties

Property	Method	Unit	Value
Thickness	ASTM D5199-12	mm	8.0
Density	ASTM D792-20	g/cm3	0.95
Compressive Strength @ Yield	ASTM D6364-06	kPa	1500
Deformation at Yield	ASTM D6364-06	mm	1.37
Strain @ yield (measured)	ASTM D6364-06	%	17%
OIT	ASTM D3895-19	(min)	75

CONCLUSION

In conclusion, the study demonstrates the significant advantages of using bimodal PE resins in geonet applications, particularly in harsh environmental conditions. The bimodal molecular weight distribution of bimodal PE resins provides a unique combination of low and high molecular weight benefits, resulting in materials with superior strength, toughness, and stress crack resistance.

The comparative analysis of bimodal and unimodal resins clearly shows that bimodal resins, such as Sample C, exhibit exceptional breaking strength while improving SHM and ESCR. These properties are crucial for ensuring the long-term durability and performance of geonets in demanding applications like mining, oil & gas, and wastewater treatment.

The trial of resin Sample C in the manufacturer's geonet production line further validated its suitability for geonet applications. The material demonstrated excellent compressive strength, deformation at yield, and OIT, indicating its robustness and resistance to environmental stressors. The enhanced performance characteristics of bimodal PE resins make them ideal for use in geotechnical and environmental applications, where durability and reliability are paramount. This study underscores the importance of molecular weight distribution and comonomer placement in polymer design, highlights the potential of bimodal PE resins in meeting the challenges of modern engineering and environmental sustainability.

Future work may include long-term field validation of the geonet in operational mining environments, evaluation under cyclic loading conditions, and further optimization of antioxidant packages tailored to specific site chemistries. These efforts will help refine the material's performance envelope and ensure reliability across a broader range of applications.

REFERENCES

[1]Sati, R., Beaumier, D., (2024). Stress-Cracking Resistance of a Bi-modal PE-RT HDPE Geomembrane, Layfield, Richmond, BC, Canada.

[2]Patterson, S., Spalding, M. (2012) Design Innovations of High Density Polyethylene Pipe Grade Resins, Antec 2012

[3]Rowe, R.K., Sangam, H. (2002) Durability of HDPE geomembranes, Geotextimes and Geomembranes 20 pages 77-95

ISO 18488. Polyethylene (PE) materials for piping systems — Determination of Strain Hardening Modulus in relation to slow crack growth, International Organization for Standardization, Vernier (Geneva), Switzerland.

ASTM D 1693. Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics, ASTM International, West Conshohocken, Pennsylvania, USA.

ASTM D 5322-17. Standard Practice for Laboratory Immersion Procedures for Evaluating the Chemical Resistance of Geosynthetics to Liquids

GRI – GC8. Test Methods, "Determination of the Allowable Flow Rate of a Drainage Geocomposite", Geosynthetic Institute, Folsom, Pennsylvania, USA.

GRI – GN4. Test Methods, "Required Properties and Testing Frequency for Biplanar Geonets and Biplanar Geonet Composites", Geosynthetic Institute, Folsom, Pennsylvania, USA.

Plasticpipes.org. Extracted from https://plasticpipe.org/pdf/chapter03.pdf, Plastics Pipe Institute. Material Properties, Chapter 3. Pg 53.